402700

UNCLASSIFIED

STUDY OF PHYSICAL AND CHEMICAL CHARACTERISTICS OF BALLOONS AND BALLOON MATERIALS

FINAL REPORT

Signal Corps Contracts:	DA-36-039-SC-84925 and DA-36-039-SC-90747
SC Technical Requirement No.:	SCL-5205A, 26 Aug 1959 w/Amend. 1, 13 Sept 1961
Department of the Army Project Nos.:	3A99-07-001-08 and 3M36-21-001-04

Period covered by this Report:
25 April 1960 - 21 December 1962

The object of this study is to further the investigation of the physical and chemical characteristics of balloons and balloon materials originated in Signal Corps Contract No. DA-36-039-SC-72386 and continued in Signal Corps Contract No. DA-36-039-SC-78239.

Prepared by: Eric Nelson and Herman Newstein

Edited by: John Kantor

Raysam Corporation of America
27 Kentucky Avenue
Paterson 3, New Jersey

TABLE OF CONTENTS

(continued)

TABLE OF CONTENTS (continued)

FACTUAL DATA (continued)

(continued)

TABLE OF CONTENTS (continued)

FACTUAL DATA (continued)

PURPOSE

The aims of this study were to improve the performance of meteorological balloons by improvements in the basic formulations, by revised or new methods of pretreatment or preconditioning, and by modification of the aerodynamic shape of such balloons.

This work will be performed according to the following schedule:

TASK A: STUDY OF BALLOON FILMS AND THEIR EFFECT ON BALLOON FLIGHT PERFORMANCE

- Phase 1: Study of the Literature
- Phase 2: Study of Raw Materials
- Phase 3: Development of Formulations with Desirable Film Properties
- Phase 4: Correlation of Film Properties with Flight Data

TASK B: EFFECT OF FLIGHT CONDITIONS ON BALLOON FILM PERFORMANCE

- Phase 1: Effect of Pre-elongation
- Phase 2: Effect of Ozone
- Phase 3: Effect of Infra-Red Radiation
- Phase 4: Effect of Ultra-Violet and Other Short-Wave Radiation
- Phase 5: Correlation of Physical Properties with Flight Performance
- Phase 6: Prediction of Balloon Performance

TASK C: STUDY OF BALLOON CONFIGURATION

- Phase 1: Design and Construction of Equipment
- Phase 2: Construction of One-Piece Balloons for Flight Testing
- Phase 3: Construction of Balloons having Mechanical Attachments to Improve Rate of Ascent
- Phase 4: Construction of Balloons having Selective Compound Modulation

ABSTRACT

The following is a resume of the work performed during the period from 25 April, 1960, through 21 December, 1962:

TASK A: STUDY OF BALLOON FILMS AND THEIR EFFECT ON BALLOON FLIGHT PERFORMANCE

Phase 1: Study of the Literature

As a result of a continuous study of the literature throughout this contract, attention was drawn to three possibly valuable compounding ingredients. Tinuvin 'P' was described as being effective in preventing degradation of natural rubber by ultra-violet radiation by the Geigy Chemical Corporation. Mobilsol 'L' was suggested as a low-temperature plasticizer by the Mobil Oil Company. B.T.N. was offered by W. T. Henley as a replacement for N.B.C.

A bulletin from E. I. duPont de Nemours described the use of Thiocarbanilide and Diphenyl Guanidine for low-temperature cures in neoprene compounds.

Phase 2: Study of Raw Materials

Part A: Neoprene Polymers

Following conferences with Du Pont, at which the desirability of developing neoprene latices specifically designed for use in meteorological balloons was discussed, six experimental polymers were submitted for evaluation. Of these polymers, only ECD-307 showed interesting elongation characteristics at room temperature and at -40°C, but its room-temperature modulus was undesirably low. Blending these polymers with other commercial polymers was ineffective as a means of improving physical properties.

Four commercially-available polymers were also evaluated. Neoprene 673 and Neoprene 450 appeared to have value, the former because of its high modulus and tensile strength, the latter because of its high room-temperature elongation.

Additional work was conducted using blends of Neoprene 750 with Neoprene 571 and with Neoprene 400. The importance of the type of plasticizer used in these compounds on the modulus was clearly demonstrated.

A comprehensive study of the effect of aging neoprene latices before compounding and the effect of aging the compounded latex was conducted.

ABSTRACT (continued)

TASK A, Phase 2 (continued)

Part B: Plasticizers

Blends of plasticizers were evaluated to determine their effect on the low-temperature characteristics of compounds. Indications were obtained that in certain cases a blend of two plasticizers was more effective than either one by itself.

Mobilsol 'L', a plasticizer supplied by The Mobil Oil Company, was evaluated and shown to have poor low-temperature characteristics.

Butoxy Ethyl Oleate from Kessler Chemical Company was evaluated and shown to give almost identical properties to those obtained with Paraflux C-325.

In addition, two other plasticizers were evaluated. They were Ohopex R-9, supplied by Stoney-Mueller, and Plasticizer SC from Harwick Standard Chemical Company. Both materials were unsuitable.

Part C: Antioxidants and Antiozonants

Agerite DPPD from R. T. Vanderbilt was evaluated an an antiozonant and shown to be superior to N.B.C. Akroflex CD from Du Pont was shown to be equal to N.B.C. These antiozonants were evaluated because of the difficulties encountered when trying to prepare dispersions of Thermoflex 'A' which had previously been shown to provide excellent ozone protection.

Agerite DPPD was also evaluated in compounds containing Lytron 615, a polystyrene latex which imparts high modulus when blended with neoprene latex but has very poor ozone resistance.

Further work with Wingstay 'T' was carried out, not in order to measure its effectiveness as an antioxidant but to confirm its side effect of increasing the elongation of neoprene compounds.

B.T.N. from Henley Chemical Company was evaluated and shown to be equivalent to N.B.C. when used in meteorological balloon formulations.

Part D: Accelerators

The accelerator, Merac, from Pennsalt Chemical Corporation, was evaluated in high- and low-modulus dayflight and dual-purpose compounds and shown to possess certain advantages.

ABSTRACT (continued)

TASK A, Phase 2, Part D (continued)

The effect of varying the amount of accelerator in a compound over a range from 0.5 parts to 3.0 parts was determined, and the possibilities of increasing low-temperature elongation by such means was illustrated. Such improvement was, however, confined to day-flight compounds.

The value of Thiocarbanilide was determined as a low-temperature curing accelerator for neoprene. Preliminary tests indicated that desirable properties could be obtained.

Part E: Polymers other than Neoprene

Poly-isoprene latex as supplied by Shell Chemical Corporation was evaluated, and the difficulties encountered in its use are described. In addition, compounds were prepared based on a natural latex. It was shown that although generally satisfactory physicals can be obtained, the ozone resistance was still very poor even when the newly available, improved antiozonants were employed.

Part F: Reinforcing Fillers

Mistron Vapor, supplied by The Sierra Talc Company, was evaluated as a reinforcing filler for balloon compounds. It was shown that improvement in room-temperature modulus and tensile strength can be obtained without loss of any other properties.

Zinc Resinate was also evaluated as a possible means of introducing zinc ions in an emulsion form. The results were unsatisfactory.

Phase 3: Development of Formulations with Desirable Film Properties

Part A: High-Altitude Balloon Compounds

An evaluation of all the raw materials investigated in Phase 2 was made, giving careful consideration to the advantages and disadvantages possessed by each one. In all, fifteen compounds were designed which were considered suitable for making day-flight balloons, some of them being derived from several series of compounds which were first evaluated in order to determine optimum ratios of certain of the ingredients involved.

ABSTRACT (continued)

TASK A, Phase 3, Part A (continued)

Balloons were manufactured from six of these compounds and flown with the major purposes of evaluating in flight the effect of improving ozone resistance by the use of Agerite DPPD (particularly in the case of compounds containing Lytron 615), the effect of increasing the modulus with Neoprene 400, the effect of the accelerator Merac, and the effect of increasing the compound elongation at room temperature and at -40°C.

Part B: Dual-Purpose Balloon Compounds

Thirty dual-purpose compounds were designed and evaluated. These compounds were, in general, based on the information obtained in Phase 2 and were principally developed with the objective of producing balloons capable of consistent performance by day and night to 120,000 feet.

Compounds were designed to determine the value of blends of Dibutyl Sebacate and Butyl Oleate, and also the value of Dibutyl Sebacate as the sole plasticizer with Neoprene 400 blends. Compounds containing Merac, similar to those developed in Phase 3, Part A, were produced, and the value of Mistron Vapor as a means of increasing the modulus of high-plasticizer compounds was demonstrated. Compounds having unusually high elongation at -70°C were also developed.

Of the thirty compounds developed, ten were used to manufacture balloons which were submitted for flight testing.

Part C: Fast-Rise Balloon Compounds

One compound was developed for fast-rise balloons. This contained Mistron Vapor as a reinforcing agent to produce high modulus, and balloons were manufactured for use in Task C, Phase 3, the study of balloons having mechanical attachments to improve rate of ascent.

Phase 4: Correlation of Film Properties with Flight Data

Part A: High-Altitude Balloons

Flights were conducted with balloons made from A3-105, and it was shown that consistent performance to 130,000 feet can be obtained with balloons weighing 2500 grams made from this compound. However, the performance of balloons weighing 6000 grams were very erratic. Attempts to improve this performance by protecting the larger balloon at launch by enclosing it in a smaller (800 gram) balloon still produced erratic performance.

ABSTRACT (continued)

TASK A, Phase 4, Part A (continued)

Balloons made from compounds containing Lytron 615 and Agerite DPPD were consistent in performance but the altitude was low, probably because of the darkening produced by the Agerite DPPD.

Flights conducted with 2500-gram balloons made from compound A3-101 were extremely consistent and also averaged 130,000 feet as did those made from A3-105.

Finally, 1000-gram balloons made from a high-elongation compound, A3-157, performed extremely well, consistently reaching altitudes of 120,000 feet, which is in the order of 15,000 feet higher than this size balloon normally achieves.

Part B: Dual-Purpose Balloons

Good results with 600-gram balloons were obtained using compound A3-103. Compound A3-104, as laboratory-determined physical properties indicated, was an improvement of A3-103 and gave very satisfactory and consistent performance to 100,000 feet by both day and night. Larger balloons, designed to reach altitudes of 120,000 feet, were very erratic, particularly at night.

Compound A3-106 was shown to give excellent results by both day and night up to 100,000 feet. Balloons weighing 2500 grams from the same compound were consistent at night but somewhat less so in the daytime. Balloons weighing 1750 grams performed consistently well to 120,000 feet by both day and night in the first series of tests but were less reliable in the second series. Further flights failed to duplicate the first series, and increasing the plasticizer content and/or the antiozonant failed to produce any improvement. The consistency was much improved, however, by increasing the wall thickness slightly, and reliable 120,000-foot balloons were produced by this means from compound A3-106.

Satisfactory 120,000-foot balloons were also produced from compound A3-127, although this compound produces 100,000-foot balloons that are inferior to those made from compound A3-106.

Flights were conducted with 1000-gram balloons made from compound A3-106 but which were cured for times and at temperatures below the optimum indicated by laboratory-determined physical properties. Some improvement in altitude appeared to be attainable by reducing the state of cure, but then performance in general seemed to be less consistent.

ABSTRACT (continued)

TASK A. Phase 4. Part B (continued)

Balloons weighing 3000 grams made from compound A3-107 showed excellent performance in a limited series of flights, while balloons made from compound A3-130 which contains Neoprene 400 did not achieve the expected results. When balloons containing B.T.N. in place of N.B.C. were flown, equal performance was obtained.

Compounds A3-132 and A3-136, both of which contained Merac, produced 1000-gram balloons equal in performance to those made from A3-106.

Flights with balloons made from compound A3-129 which contained Butoxy Ethyl Oleate in place of Paraflux C-325 were slightly superior to those made with balloons from A3-106.

Compound A3-133 using Dibutyl Sebacate as the only plasticizer were soft, difficult to handle, and performed poorly.

Compound A3-138, a development of compound A3-104 produced reliable 100,000-foot, dual-purpose balloons; however, 1500-gram balloons made from this compound failed to perform, being inferior to the 1000-gram balloons.

Balloons made from both compounds A3-106 and A3-138 modified by increasing the plasticizer content were shown to be satisfactory for use in the Tropical Zone at night.

Balloons weighing 1000 grams made from compound A3-165, which is based on Neoprene 673, performed very poorly. A series of laboratory tests with 100-gram balloons made from the same compound showed that such balloons inflate very badly insofar as both shape and bursting volume is concerned.

Part C: Fast-Rise Balloons

Thick-walled balloons were flown. These were made from compounds A3-102 and A3-134, both of which have high modulus. The results obtained were only fair, and the rates of ascent failed to reach the anticipated figures.

Similar, but lighter and shorter, balloons manufactured from compounds A3-138 and A3-106 showed fairly good performance to relatively low altitudes.

ABSTRACT (continued)

TASK B: EFFECT OF FLIGHT CONDITIONS ON BALLOON FILM PERFORMANCE

Phase 1: Effect of Pre-elongation

A study of the effect of pre-elongation on the properties of day-flight and dual-purpose compounds furnished an explanation for some of the apparently anomalous behavior of balloon performance.

Phase 2: Effect of Ozone

An ozonator was purchased from G. F. Bush Associates, and the methods of calibration and operation are described. A comprehensive investigation of the ozone resistance of balloon films was carried out. Day-flight and dual-purpose compounds were examined at different elongations and under unilateral and multilateral stress. It was shown that resistance to ozone depends on the nature of the compound, the degree of elongation, and the type of stress.

Phase 3: Effect of Infra-Red Radiation

The spectral characteristics of neoprene balloon films were determined in the infra-red region. Also, an exhaustive study of the radiation load on a balloon in the free atmosphere was conducted.

Compounds were designed with high absorption in the infra-red and with less than normal absorption. Flights were performed with balloons made from such compounds, and their performance was successfully correlated with the theoretical findings of the infra-red radiation study.

Phase 4: Effect of Ultra-Violet and Other Short-Wave Radiation

The effect of ultra-violet radiation on balloon films was examined, and it was shown that, in general, the deterioration was insignificant if the tests were conducted in an atmosphere of nitrogen. When the tests were conducted in air, the deterioration due to the creation of ozone was much greater than any direct effect of the ultra-violet radiation itself.

Phase 5: Correlation of Physical Properties with Flight Performance

Balloons were flown to determine the effect of increasing the absorption of solar radiation, and it was demonstrated that substantial loss in altitude is obtained in the daytime if the compound used shows high infra-red absorption.

ABSTRACT (continued)

TASK B. Phase 5 (continued)

Flights were conducted with balloons containing Agerite DPPD to evaluate the improvement in ozone resistance. The darker color of these balloons, however, increased the absorption of infra-red radiation with a consequent loss in altitude.

Flights with balloons having very low infra-red absorption were consistent but no better in altitude attained than standard balloons.

Phase 6: Prediction of Balloon Performance

Part A: Determination of Burst Altitude from Residual Elongation

A system of nomograms was developed for predicting balloon flight performance using the residual elongation at a given temperature as the basis.

Part B: Determination of Dimensions of Fast-Rising Balloons

A theoretical study of the dimensions of fast-rise balloons was carried out. Using the performance of a standard balloon as a basis, it was shown that accurate prediction of the performance of fast-rise balloons could be made.

Part C: Determination of Physical Properties of Constant-Level Balloon Films

A theoretical determination was made of the physical characteristics necessary to produce a balloon capable of reaching and maintaining a constant altitude.

Part D: Analysis of Stress in Sounding Balloons

An analysis of the stress in sounding balloons showed that, assuming the balloon to be perfectly spherical, the area of maximum stress was adjacent to the neck. Because a balloon is not truly spherical, the area of greatest stress moves toward the center of the balloon.

A series of photographic experiments was conducted to observe exactly where a balloon breaks on inflation, and these experiments and the photographic equipment are described.

Part E: Effect of the Modulus-Elongation Characteristics on the Shape of Inflating Balloons

The relationship between the slope of the modulus-elongation curve and the shape of an inflating balloon was demonstrated. Flights made with uncured balloons confirmed the effect of the shape of the balloon on ascensional rate.

ABSTRACT (continued)

TASK C: STUDY OF BALLOON CONFIGURATION

Phase 1: Design and Construction of Equipment

Four prototype dipping forms were designed and fabricated with a view to producing a gel which would inflate to form a tear-drop shaped balloon. Considerable difficulties were encountered in producing such a gel.

Phase 2: Construction of One-Piece Balloons for Flight Testing

Flights were conducted with balloons having a 2/1 length/diameter ratio, and it was demonstrated that this type of balloon had a greater ascensional rate than a similar spherical balloon, particularly at relatively low free lift.

Phase 3: Construction of Balloons having Mechanical Attachments to Improve Rate of Ascent

Flights were also conducted with 2/1 length/diameter ratio balloons to which a tubular tail was attached. No improvement in ascensional rate was obtained, and further flights with spherical balloon assemblies with tails having about the same weight as the tubular balloons showed higher rates of ascent.

A series of flights was conducted with spherical balloons made in varying wall thicknesses and from various compounds which had substantially different modulus characteristics. Tails were attached to these balloons in the normal manner.

The flights were carefully analyzed, the ascensional rate being determined over 10,000-foot intervals. As a result of this analysis, it was possible to determine with considerable confidence the physical characteristics required for assemblies of this type.

Phase 4: Construction of Balloons having Selective Compound Modulation

Efforts were made to induce a streamlined shape in a spherical balloon by partial post plasticizing to reduce the modulus. It was shown that the desired shape could be obtained but only at a considerable sacrifice of bursting volume.

PUBLICATIONS, LECTURES, REPORTS, AND CONFERENCES

No publications, lectures, or reports resulted from this study during the period covered by this report.

CONFERENCES:

May 10, 1960, at Evans Signal Laboratories, Belmar, New Jersey.

Present were:	Mr. R. Leviton	Air Force Research
	Mr. L. P. Panak	USAERDL
	Mr. M. Sharenow	USAERDL
	Mr. G. C. Guard	Kaysam Corporation
	Mr. J. Kantor	Kaysam Corporation
	Mr. E. Nelson	Kaysam Corporation

Among other subjects not connected with this contract, the film study was discussed briefly. The general approach as given in the technical proposal was approved by USAERDL. It was agreed to call a preliminary conference with Dr. London and Dr. Newstein, consultants from New York University, to be followed by a broader conference at which USAERDL representatives would be present.

* * *

May 18, 1960, at Kaysam Corporation of America,
27 Kentucky Avenue, Paterson, New Jersey.

Present were:	Dr. Julius London	New York University
	Dr. H. Newstein	New York University
	Mr. L. P. Panak	USAERDL
	Mr. M. Sharenow	USAERDL
	Mr. G. C. Guard	Kaysam Corporation
	Mr. J. Kantor	Kaysam Corporation
	Mr. E. Nelson	Kaysam Corporation

The purpose of this meeting was to brief Dr. London and Dr. Newstein on some of the problems of high-altitude meteorological balloon flights.

The general bahavior of meteorological balloons during flight was described, and the fundamental problem of extending the film at low temperatures was discussed. Mr. Sharenow reported on the use of balloons filled with carbon dioxide and on the general work which had been done on the temperatures inside and outside the balloon.

Mr. Panak inquired as to the significance of the temperature inside the balloon, and it was pointed out that this affects the temperature of the balloon film itself. Because of the extreme thinness of the film, it is impossible to measure its actual

CONFERENCES (continued)

temperature; by measuring temperatures on either side of the film, the approximate temperature of the film may be determined. Dr. London pointed out the importance of heat conduction through the film.

Mr. Kantor asked what the effect of electromagnetic and electrostatic forces would be. Dr. London stated that creation of electromagnetic or electrostatic stress might be troublesome but that any heating effect of such forces would be minimal.

It was suggested by Mr. Sharenow and generally agreed that the study of the effect of infra-red radiation should come first. This would be followed by a study of the effect of other types of radiation including ultra-violet and shortwave radiation.

Dr. London said that determination of the entire heat load outside and inside the balloon is essential; and in order to determine this, the absorption spectrum characteristics of the film are required. Mr. Nelson agreed to find out from Du Pont what information regarding the absorption spectra of neoprene films is available. If necessary, balloon films will be sent to a testing laboratory in order to obtain this information.

Black balloons and radiation to and from such balloons were discussed.

The effect of ozone on neoprene films was also discussed. Dr. Newstein advised that at altitudes approaching 150,000 feet the balloon will be encountering atomic oxygen. No information regarding the effect of atomic oxygen of neoprene is available.

It was agreed that the main points to be investigated are:

1. Effect of ozone and atomic oxygen.
2. Effect of all types of radiation, in particular their effect on the balloon film temperature.
3. Effect of pre-elongation.

Dr. London and Dr. Newstein agreed to make a preliminary study of the general problem and to present an outline of their proposed method of attack early in June. Kaysam Corporation will perform or have performed the laboratory testing which this program will require, and Dr. London and Dr. Newstein will resume their phase of the study in September.

CONFERENCES (continued)

January 26, 1961, at Kaysam Corporation of America
27 Kentucky Avenue, Paterson, New Jersey.

Present were:		
	Mr. R. Leviton	Air Force Research
	Mr. M. Sharenow	USAERDL
	Dr. J. London	New York University
	Dr. H. Newstein	New York University
	Mr. G. C. Guard	Kaysam Corporation
	Mr. J. Kantor	Kaysam Corporation
	Mr. E. Nelson	Kaysam Corporation

Dr. London reported on the results of the infra-red studies conducted by Dr. Newstein and himself. At night, the radiation upwards is greater from the earth than it is from the clouds. It was also stated that the balloon is always losing more radiation than it receives.

It was assumed that the balloon is in thermal equilibrium throughout and that the film and gas are at the same temperature. The validity of this assumption was questioned in day-time flights, although the assumption may be correct at night.

Dr. London said it would be helpful to know the thermal conductivity of a neoprene balloon film. Mr. Nelson agreed to obtain this information. Mr. Sharenow also agreed to endeavor to determine the surface thermal conductivity by attaching bead thermistors to the balloon film. Initially, this will be done with a piece of film; and if this is successful, attempts will be made to obtain the same information on a balloon inflated with hydrogen.

Mr. Sharenow asked if the effect of using some carbon dioxide in the balloon had been studied. Dr. London said that although this might be of value in the daytime, it would be a disadvantage at night.

Dr. Newstein showed the infra-red absorption spectra for standard neoprene balloon film. It was agreed that Kaysam would supply Dr. Newstein with samples of black balloon film, and also of white film which is presently being evaluated by Kaysam, for infra-red absorption spectrum analysis.

The effect of ultra-violet radiation was discussed. Little, if any, information is available on the action of ultra-violet radiation on neoprene. It was suggested that experiments be set up using a secondary chamber inside the cold box. This chamber would be filled with Argon since ultra-violet radiation creates ozone if oxygen is present. This would interfere with the evaluation of the effect of ultra-violet radiation and must be excluded by the use of an inert atmosphere.

CONFERENCES (continued)

Dr. Newstein presented and explained the use of the altitude prediction curves which he had prepared. These use residual elongation as a means of determining where any given balloon will break assuming the ambient temperature is known or can be assumed.

Dr. Newstein also suggested an improved means of determining physical characteristics at low temperatures, using automatic recorders. This will be investigated.

Mr. Nelson reviewed the progress made during the last quarter and outlined the program for the next quarter in order to bring Mr. Leviton up to date on the status of the contract.

* * *

January 24, 1962, at the Henry Hudson Hotel, New York, New York.

Present were:	Mr. R. Leviton	Air Force Research
	Mr. M. Sharenow	USAERDL
	Dr. H. Newstein	New York University
	Mr. G. C. Guard	Kaysam Corporation
	Mr. J. Kantor	Kaysam Corporation
	Mr. E. Nelson	Kaysam Corporation

The main purpose of this meeting was to discuss the most recent developments arising from Contract No. DA-36-039-SC-84925.

Mr. Nelson gave a brief resume' of the achievements of the past three months. The Seventh Quarterly Report contains all the information given at this meeting in full detail.

A discussion of the results of fast-rise balloon flights followed. It was pointed out that the rate of ascent of streamlined, fast-rise balloons generally increases until altitudes of approximately 40,000 feet have been reached. The balloon then ascends at a fairly constant speed for about 30,000 feet and finally decelerates more or less sharply during the latter stages of the flight. This deceleration frequently results in the average rate falling below 1700 feet per minute.

Various reasons for this deceleration were put forward by Messrs. Sharenow, Kantor, and Nelson. These included distortion of the balloon during the daytime resulting from variations in modulus throughout the balloon due to uneven heating by solar radiation; distortion due to the increase in effective thickness of the lower part of the balloon as the tail section is drawn up around the expanding upper balloon; loss of effective streamlined shape as the tail section is drawn up around the expanding upper balloon; and loss of effective lifting force due to increases in the internal pressure as the balloon expands and the modulus increases.

CONFERENCES (continued)

It was agreed that all the above avenues should be explored in order to determine the true reason for the loss in ascensional rate at higher altitudes.

Dr. Newstein showed some photographs of balloons at the point of bursting. The limited number of photographs taken to date indicate that the burst generally occurs at the equator of the balloon. So far, 30-gram balloons inflated with helium have been photographed, and it is proposed to extend this program to larger balloons which will be inflated with helium to the appropriate free lift and then with air until the bursting point is reached.

Flights of ML-537 balloons were also discussed. These were unsatisfactory in the Tropical Zone but extremely satisfactory in the Temperate Zone. Standardization on this balloon by the Air Force may be anticipated.

The deficiencies of the low-temperature cabinet in the possession of Kaysam Corporation were discussed. Mr. Leviton mentioned two low-temperature cabinets, one or both of which might shortly become available. He agreed to investigate the situation and advise us.

* * *

May 8, 1962, at the Du Pont Laboratories, Wilmington, Delaware.

Present were:		
	Mr. D. Thompson	Du Pont Laboratories
	Mr. J. Fitch	Du Pont Laboratories
	Mr. D. Gorman	Du Pont Laboratories
	Mr. E. Nelson	Kaysam Corporation

The major purpose of this visit to the Customer Service Laboratories of E. I. du Pont de Nemour was to resolve the impasse concerning Neoprene 673 and to determine whether any additional types of neoprene were available for evaluation.

Messrs. Thompson and Fitch advised that two or three new experimental polymers had either just been or were about to be passed on for final evaluation. Pending the results of these tests, the samples would be made available to us shortly.

The problem of forwarding an intermediate quantity of Neoprene 673 is due to the fact that this polymer is made for only one customer in Europe. This customer has agreed to take a production run which amounts to approximately 4000 gallons, and investigation of the situation revealed that no further order could be anticipated until next fall.

CONFERENCES (continued)

In the meantime, Du Pont could make up to about 10 gallons using laboratory equipment. This is unsatisfactory for two reasons. Firstly, laboratory-produced samples are not necessarily representative of production material; and secondly, this is not sufficient to make sounding balloons for flight testing.

The problem was finally taken to Mr. R. Griffin, and he advised that a drum of Neoprene 673 had been located in Louisville. This is old material, probably over one year old. Du Pont was willing to give us this drum at no charge on the basis that, if the results obtained were bad, it would not necessarily condemn this type of polymer.

Agreement was reached on this basis. However, a few days after this visit, we were advised that Du Pont had re-purchased five drums of the latex from their customer. This is from their last production run and is fully representative. Purchase of these five drums has now been authorized.

* * *

May 21, 1962, at Kaysam Corporation of America
27 Kentucky Avenue, Paterson, New Jersey

Present were:	Mr. R. Leviton	Air Force Research
	Mr. J. LeBedda	USAERDL
	Mr. M. Sharenow	USAERDL
	Mr. G. C. Guard	Kaysam Corporation
	Mr. J.Kantor	Kaysam Corporation
	Mr. E. Nelson	Kaysam Corporation

Mr. Nelson gave a detailed resume' of the work conducted during the past four months. The results of a visit to Du Pont in Wilmington, Delaware, were reported. As a result of this visit, five drums of Neoprene 673, which has good elongation coupled with high tensile strength and modulus, are being made available to Kaysam. This latex is in very limited production, and obtaining a sufficient quantity to make sounding balloons had been presenting a problem.

Means of formulating neoprene compounds to give room-temperature cures were described, and this was indicated as a profitable line of investigation.

Reference was made to the Hycar sample which was received and which gave films of extremely high (10,000 psi) tensile strength. It was agreed that this material should be investigated further. The fact that its most probable use would be in constant-level

CONFERENCES (continued)

balloons, renders it of limited interest since there is no immediate requirement for this type of balloon.

It was agreed that natural latex should be re-evaluated at this time. No work has been conducted on this elastomer for at least ten years, insofar as meteorological balloons are concerned. During this time there have been considerable advances in rubber compounding, particularly in protection against ozone attack, one of the major causes for the poorer performance of natural latex balloons.

There was some discussion of the effect of pre-elongation and of how the behavior of pre-elongated balloon films can explain certain flight anamolies. It is acknowledged that if this phenomenon were used to advantage, the bursting altitude of large balloons should be substantially increased. It was agreed that the Signal Corps will perform tests in connection with pre-elongation with a view toward obtaining higher altitudes, faster rates of ascent, and overcoming freezing in the troposphere.

Mr. Sharenow suggested investigation of the use of a chemical heat generator placed in the neck of the balloon to heat the gas as the balloon passes through the minimum-temperature zone.

No work is being planned on the effect of ozone and radiation on balloon films other than in the use of natural latex balloons.

It was agreed that additional photographic analysis of bursting balloons should be conducted in conjunction with Dr. Newstein. It was also acknowledged that further investigation was desirable on the relationship between the modulus-elongation curve, the shape of an expanding balloon, and the altitude and ascensional rate.

Mr. Leviton stressed the necessity of developing compounds suitable for use in the Arctic and Tropical Zones. A limited number of flights in both areas indicate that compounds suitable for the manufacture of 100,000-foot balloons which will perform under these stringent conditions will shortly be available.

FACTUAL DATA

TASK A: STUDY OF BALLOON FILMS AND THEIR EFFECT ON BALLOON FLIGHT PERFORMANCE

Phase 1: Study of the Literature

The current literature, particularly that concerning newly developed raw materials, was continuously studied throughout these contracts.

Among the letters to the editor in Volume II, Issue No. 6, of the Journal of Applied Polymer Science is one from J. R. Dunn and S. G. Fogg of the British Rubber Producers Research Association which describes Tinuvin 'P'. This product of the Geigy Chemical Corporation is said to be most effective in preventing degradation of natural rubber compounds by ultra-violet light. A sample of the material was obtained.

A sample of Mobilsol 'L', a product of the Mobil Oil Company, which is claimed to be an excellent low-temperature plasticizer, was also received as a result of such study. This is a hydrocarbon type and is representative of a class of plasticizers not hitherto evaluated.

It was also learned that a material which is apparently identical to N.B.C. and is sold by W. T. Henley under the tradename of B.T.N. is now available. It was considered worthwhile to obtain a sample of this material and to compare it with N.B.C. from Du Pont.

A bulletin issued by E. I. du Pont de Nemours suggested the use of Thiocarbanilide and Diphenyl Guanidine in neoprene latex compounds to provide low-temperature and even room-temperature cures. The results of the investigation resulting from this work are reported in Task A, Phase 2, Part D.

Phase 2: Study of Raw Materials

Part A: Neoprene Polymers

The possibilities of obtaining new neoprene polymers were discussed with members of the Du Pont organization at a meeting in Wilmington, Delaware.

It was pointed out that there are no neoprene polymers specifically designed to have the unique qualities required for meteorological balloons. The necessary properties were described to the Du Pont personnel, and it was suggested that polymers could have been developed for general use and discarded which might have very desirable properties for meteorological balloon films.

FACTUAL DATA (continued)

TASK A, Phase 2, Part A (continued)

Du Pont agreed to re-evaluate existing polymers on this basis, as well as develop new ones. During the course of this study they submitted samples of six new experimental polymers and four polymers which are or have been commercially available.

The six experimental polymers were identified as ECD-300, ECD-307, ECD-314, ECD-416, ECD-417, and ECD-418. According to information supplied by the manufacturer, ECD-300 has good resistance to crystallization and excellent ozone resistance, and ECD-307 has poor resistance to crystallization and good ozone resistance. ECD-314 was reported to have unusually high elongation. ECD-416 was described as a rapidly crystallizing polymer, ECD-417 as having extremely high elongation and good tensile strength, and ECD-418 as also having high elongation when cured with zinc oxide at 70°C.

Accordingly, six compounds were prepared, the formulations for which are given in Table 1. Plates were dipped from them according to standard procedure and cured for 60, 90, and 120 minutes at 240°F, 260°F, and 280°F, with the exception of compound A2a-21 which was cured for 45 and 90 minutes at 160°F. Physical properties were determined at room temperature and at -40°C. The results of these tests are given in Tables 2 and 3.

A study of these results shows that polymers ECD-300 and ECD-307 show unusually high room-temperature elongation. This is, however, in both cases coupled with a low room-temperature modulus which would render balloons made from these compounds very fragile and difficult to handle at launching.

Polymer ECD-300 shows good elongation at -40°C until cured at 280°F when it is virtually frozen if cured for more than 60 minutes. It is only these cures which show acceptable room-temperature modulus, and it would appear therefore that polymer ECD-300 is of no interest.

Polymer ECD-307 shows unusually high elongation at -40°C. This, coupled with its high room-temperature elongation, renders it promising for high-altitude balloon compounds; but, unfortunately, its room-temperature modulus is even lower than that of ECD-300.

Compound A2a-12 substantiates the manufacturer's claim of high room-temperature elongation for ECD-314, but the modulus is even lower than that of ECD-300 and ECD-307. In addition, the elongation at -40°C is no higher than that of standard production neoprene polymers and does not follow the room-temperature elongation pattern.

FACTUAL DATA (continued)

TASK A, Phase 2, Part A (continued)

TABLE 1

FORMULATIONS OF COMPOUNDS CONTAINING EXPERIMENTAL POLYMERS

Formulation No.	A2a-10	A2a-11	A2a-12	A2a-19	A2a-20	A2a-21
Neoprene ECD-300	100.0	-	-	-	-	-
Neoprene ECD-307	-	100.0	-	-	-	-
Neoprene ECD-314	-	-	100.0	-	-	-
Neoprene ECD-416	-	-	-	100.0	-	-
Neoprene ECD-417	-	-	-	-	100.0	-
Neoprene ECD-418	-	-	-	-	-	100.0
Zinc Oxide	5.0	5.0	5.0	5.0	5.0	5.0
Neozone 'D'	2.0	2.0	2.0	2.0	2.0	2.0
N.B.C.	3.0	3.0	3.0	3.0	3.0	3.0
Accelerator 833	1.0	1.0	1.0	-	-	-
Merac	-	-	-	1.0	1.0	1.0
Sunaptic Acid	1.0	1.0	1.0	1.0	1.0	1.0
Aquarex SMO	0.5	0.5	0.5	0.5	0.5	0.5
Dibutyl Sebacate	10.0	10.0	10.0	6.25	6.25	6.25

TABLE 2

PHYSICAL PROPERTIES OF COMPOUNDS A2a-10, A2a-11, A2a-12, A2a-19, A2a-20 AND A2a-21 TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
A2a-10	60	240	70	85	150	1385	1385	50
	90	240	85	95	150	1550	1340	55
	120	240	80	90	140	1605	1390	53
	60	260	80	90	135	1685	1400	56
	90	260	80	90	120	1715	1405	47
	120	260	100	115	160	1900	1235	87
	60	280	90	115	145	1980	1300	67
	90	280	120	155	235	2445	1105	82
	120	280	140	155	300	2465	1010	96
A2a-11	60	240	75	85	115	1245	1355	45
	90	240	80	95	125	1340	1305	47
	120	240	80	90	120	1390	1425	50
	60	260	80	90	125	1340	1390	52
	90	260	85	95	115	1475	1390	46
	120	260	85	95	110	1595	1420	51
	60	280	85	90	110	1350	1335	50
	90	280	90	125	150	1860	1195	55
	120	280	100	135	170	1880	1095	58
A2a-12	60	240	55	60	75	720	1665	29
	90	240	50	55	70	840	1765	28
	120	240	55	60	80	800	1680	31
	60	260	55	65	80	1020	1695	34
	90	260	65	75	90	1150	1680	36
	120	260	70	75	95	1160	1585	37
	60	280	75	85	105	1495	1410	26
	90	280	65	80	95	1350	1425	42
	120	280	85	105	145	1810	1270	53
A2a-19	60	240	510	1350	2060	2140	620	-
	90	240	530	1270	-	2000	570	-
	120	240	520	1220	-	2070	590	-
	60	260	470	1340	2200	2270	600	-
	90	260	480	1270	2300	2350	630	-
	120	260	630	1450	-	2240	520	-
	60	280	530	1320	-	2060	570	-
	90	280	590	1310	2370	2580	680	-
	120	280	610	1340	-	2200	590	-
A2a-20	60	240	90	140	280	1870	1050	-
	90	240	95	145	280	1950	1080	-
	120	240	95	160	320	2070	1110	-
	60	260	105	150	290	1660	1040	-
	90	260	95	150	290	1400	1000	-
	120	260	105	165	380	2110	1100	-
	60	280	110	160	310	2270	1160	-
	90	280	90	130	270	1400	980	-
	120	280	110	165	320	1890	1010	-
A2a-21	45	160	80	105	175	1760	1330	-
	90	160	70	100	200	2240	1360	-

TABLE 3

PHYSICAL PROPERTIES OF COMPOUNDS A2a-10, A2a-11, A2a-12, A2a-19, A2a-20 AND A2a-21 TESTED AT -40°C

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A2a-10	60	240	1275	1915	4165	4840	620
	90	240	1690	2145	4445	5420	640
	120	240	1615	2160	-	4205	580
	60	260	1445	2260	4595	4760	610
	90	260	1295	2070	-	3750	580
	120	260	2410	2685	-	4375	550
	60	280	2385	2575	5390	5675	610*
	90	280	-	-	-	2755	140*
	120	280	-	-	-	3135	40*
A2a-11	60	240	170	280	1035	4220	800
	90	240	205	290	1630	4275	750
	120	240	190	305	1505	3295	700
	60	260	220	315	1655	5030	770
	90	260	220	305	1305	3140	710
	120	260	180	240	1265	3705	730
	60	280	115	335	1490	3565	710
	90	280	245	460	2015	3965	700
	120	280	280	565	2420	4275	700
A2a-12	60	240	805	1275	-	3415	580
	90	240	720	1330	3140	3215	610
	120	240	755	1300	-	2925	580
	60	260	895	1520	3915	4730	660
	90	260	965	1590	3465	4915	670
	120	260	930	1595	3375	3965	620
	60	280	1380	2475	-	4135	580
	90	280	835	2070	4190	4620	620
	120	280	1355	1940	-	3420	570
A2a-19	60	240	2170	3475	-	3750	440*
	90	240	2455	3885	-	4955	460*
	120	240	2640	4665	-	5575	500*
	60	260	1860	3245	-	3245	400*
	90	260	2200	-	-	2855	380*
	120	260	2440	-	-	3010	380*
	60	280	1220	2210	-	2210	400*
	90	280	1750	2950	-	2950	400*
	120	280	2220	-	-	3110	380*
A2a-20	60	240	2170	2760	-	3620	520*
	90	240	-	-	-	Frozen	-
	120	240	-	-	-	Frozen	-
	60	260	-	-	-	Frozen	-
	90	260	1510	2040	-	2040	400*
	120	260	1730	1925	3525	4105	640*
	60	280	1785	2145	-	4345	540*
	90	280	2565	2565	-	5000	580*
	120	280	2320	2320	-	3515	520*
A2a-21	45	160	1980	1980	3905	4010	620**
	90	160	1890	1890	-	3870	580**

* cold flow ** severe cold flow

FACTUAL DATA (continued)

TASK A, Phase 2, Part A (continued)

Neoprene ECD-416 has very low room-temperature elongations at all cures coupled with very high modulus. It is evidently a very crystalline type, and the results obtained are similar to those obtained with Neoprene 400. As might be expected, the elongation at -40°C is also very low, and there is considerable cold flow at all cures.

Compounds made from ECD-416 appear to be very unstable, the pH dropping rapidly on standing so that coagulation occurs in less than one week.

Neoprene ECD-417 shows good elongation at room-temperature but is in no way superior to existing commercially available latices. The low-temperature elongations are somewhat lower than might be expected, and there is substantially more cold flow than the room-temperature physicals indicate.

Neoprene ECD-418 shows extremely high room-temperature elongations and has the added advantage of curing at very low temperatures. The tensile strength is satisfactory, although the modulus is a little lower than is desirable.

When ECD-418 was tested at -40°C, both cures showed severe cold flow although the ultimate elongation was fairly good. It would seem that by increasing the plasticizer content and using Mistron Vapor to raise the modulus that it might be possible to obtain films with interesting properties from this polymer.

It would appear from the above results that the room-temperature elongation of ECD-314 is high enough to permit compounding for higher modulus while still retaining unusually high elongation. Accordingly, a compound was prepared which included 20 parts of Neoprene 400 in an effort to increase the room-temperature modulus. The formulation of this compound, identified A2a-13, is given below:

	Compound A2a-13
Neoprene ECD-314	80.0
Neoprene 400	20.0
Zinc Oxide	5.0
Neozone 'D'	2.0
N.B.C.	3.0
Accelerator 833	1.0
Sunaptic Acid	1.0
Aquarex SMO	0.5
Dibutyl Sebacate	10.0

FACTUAL DATA (continued)

TASK A, Phase 2, Part A (continued)

Plates were dipped according to standard procedure and cured for 60, 90, and 120 minutes at 240°F, 260°F, and 280°F. Physical properties were determined at room temperature and at -40°C and the results of these tests are given in Table 4.

A study of these results shows that the objective of increasing the modulus to practical levels has been achieved. However, the room-temperature elongation has now been reduced to a level only slightly above that of standard production compounds. In addition, the low-temperature elongation has also been slightly impaired.

An additional compound was, therefore prepared in which the plasticizer content was raised to 15 parts in order to improve the low-temperature elongation. This compound was designated A2a-14, and its formulation is as follows:

	Compound A2a-14
Neoprene ECD-314	80.0
Neoprene 400	20.0
Zinc Oxide	5.0
Neozone 'D'	2.0
N.B.C.	3.0
Accelerator 833	1.0
Sunaptic Acid	1.0
Aquarex SMO	0.5
Dibutyl Sebacate	15.0

Plates were dipped according to standard procedure and cured for 60, 90, and 120 minutes at 240°F, 260°F, and 280°F. Physical properties were determined at room temperature and at -40°C, and the results of these tests are given in Table 5.

A study of these results shows that the elongation at -40°C has been increased as desired, but this increase has been achieved at the cost of a further reduction in room-temperature elongation and a slight reduction in modulus.

Further increase in plasticizer content will, unquestionably, result in further reduction in room-temperature elongation and modulus accompanied by a small increase in elongation at -40°C. However, the physical characteristics of this compound are now very similar to those of standard production compounds; and there would, apparently, be no advantage associated with Neoprene ECD-314.

FACTUAL DATA (CONTINUED)

TASK A PHASE 2 PART A (CONTINUED)

TABLE 4

PHYSICAL PROPERTIES OF COMPOUND A2a-13 TESTED AT ROOM TEMPERATURE AND AT -40°C

Test. Temp. (°C)	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
+20	60	240	75	100	170	1210	1280	44
+20	90	240	70	100	170	1210	1295	48
+20	120	240	70	95	160	1215	1325	50
+20	60	260	110	160	295	1655	1145	6[illegible]
+20	90	260	110	160	320	1795	1140	64
+20	120	260	110	170	320	1995	1160	70
+20	60	280	130	205	445	2135	1100	90
+20	90	280	110	185	405	2045	1080	94
+20	120	280	95	185	375	2080	1115	88
-40	60	240	780	2220	4465	4465	600	-
-40	90	240	750	2050	-	3350	570	-
-40	120	240	815	2055	-	3445	570	-
-40	60	260	1060	2675	-	4795	580	-
-40	90	260	995	2680	-	4720	590	-
-40	120	260	1175	2870	-	5060	580	-
-40	60	280	1395	3025	5670	5610	600	-
-40	90	280	1250	2925	5520	5730	610	-
-40	120	280	1365	2815	5655	6025	630	-

FACTUAL DATA (*CONTINUED*)

TASK A PHASE 2 PART A (*CONTINUED*)

TABLE 5

PHYSICAL PROPERTIES OF COMPOUND A2a-14
TESTED AT ROOM TEMPERATURE AND AT -40°C

Test Temp. (°C)	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
+20	60	240	85	145	285	1315	1085	53
+20	90	240	90	145	280	930	965	51
+20	120	240	90	150	280	1330	1105	63
+20	60	260	90	145	275	1245	1065	58
+20	90	260	95	155	285	1345	1090	51
+20	120	260	90	150	290	1500	1090	62
+20	60	280	110	165	330	1615	1085	74
+20	90	280	115	170	365	1740	1065	71
+20	120	280	115	185	375	2030	1070	75
-40	60	240	470	1325	3265	3700	630	-
-40	90	240	435	1200	3005	4450	680	-
-40	120	240	565	1275	3125	4600	650	-
-40	60	260	650	1405	3750	4585	650	-
-40	90	260	665	1445	3900	4950	670	-
-40	120	260	585	1480	3725	5095	700	-
-40	60	280	845	2065	4495	4875	620	-
-40	90	280	800	1820	4490	5245	650	-
-40	120	280	1015	2355	4730	4730	600	-

FACTUAL DATA (continued)

TASK A, Phase 2, Part A (continued)

The manufacturer also claimed that ECD-314 posessed superior ozone resistance. The ozone resistance of compound A2a-13 was, therefore, compared with that of the same compound based on Neoprene 750 and Neoprene 571 (compound A3-105).

Samples cured for 60, 90, and 120 minutes at 240°F and 280°F were evaluated at 200% and 600% elongation in an ozone concentration of 80 parts per million. The results of these tests are given in Table 6.

A study of these results shows that at all cures and elongations tested, Neoprene ECD-314 is much superior in ozone resistance to Neoprene 750. This is the case whether the time to rupture or time to initial cracking is taken as the standard of evaluation.

Therefore, there is some justification for continuing the evaluation of Neoprene ECD-314 in balloons although the physical attributed of elongation, modulus, and tensile strength show no noteworthy superiority to standard neoprene polymers.

It has previously been established that Neoprene 735, which has good low-temperature properties and excellent gel extension characteristics, has much too low a room-temperature modulus for making meteorological balloons. However, it was thought that by blending this latex with Neoprene 400 this condition could be corrected; and two compounds were designed, the formulations for which are given in Table 7.

Plates were dipped from these compounds according to standard procedure and cured for 60, 90, and 120 minutes at 240°F, 260°F, and 280°F. Physical properties were determined at room-temperature, and the results of these tests are given in Table 8.

A study of these results shows that combinations of Neoprene 400 and Neoprene 735 result in compounds with physical properties generally unsuitable for meteorological balloons. Elongations are low for compound A2a-30, and the tensile strength of A2a-31 is very low at all except the 90-minute and 120-minute at 280°F cures. The elongations of A2a-31 are also low.

There appeared to be little to be gained by determining low-temperature characteristics of either of these compounds, and no further work was done.

FACTUAL DATA (CONTINUED)

TASK A PHASE 2 PART A (CONTINUED)

TABLE 6

OZONE RESISTANCE OF NEOPRENE ECD-314

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Elongation (%)	Time to Slight Attack (mins)	Time to Medium Attack (mins)	Time to Heavy Attack (mins)	Time to Rupture (mins)	Condition at 240 minutes
A2a-13	60	240	200	-	-	-	-	no attack
	90	240	200	-	-	-	-	no attack
	120	240	200	195	235	-	-	test ended
A3-105	60	240	200	25	35	65	95	
	90	240	200	25	40	65	120	
	120	240	200	25	40	60	85	
A2a-13	60	240	600	195	-	-	-	test ended
	90	240	600	175	185	195	200	
	120	240	600	195	-	-	-	test ended
A3-105	60	240	600	25			30	
	90	240	600	25			30	
	120	240	600	25	40	60	70	
A2a-13	60	280	200	45	125	145	170	
	90	280	200	50	130	155	210	
	120	280	200	50	75	95	140	
A3-105	60	280	200	50	70	80	110	
	90	280	200	25	30	35	40	
	120	280	200	25	35	45	55	
A2a-13	60	280	600	165	210	225	240	
	90	280	600	165	235	-	-	test ended
	120	280	600	130	160	165	170	
A3-105	60	280	600	60	75	85	90	
	90	280	600		30		35	
	120	280	600				35	

FACTUAL DATA (continued)

TASK A, Phase 2, Part A (continued)

TABLE 7

FORMULATIONS OF COMPOUNDS CONTAINING NEOPRENE 735 AND NEOPRENE 400

Formulation No.	A2a-30	A2a-31
Neoprene 400	75.0	50.0
Neoprene 735	25.0	50.0
Zinc Oxide	5.0	5.0
Neozone 'D'	2.0	2.0
N.B.C.	3.0	3.0
Accelerator 833	1.0	1.0
Sunaptic Acid	1.0	1.0
Aquarex SMO	0.5	0.5
Butyl Oleate	10.0	10.0

TABLE 8

PHYSICAL PROPERTIES OF COMPOUNDS A2a-30 AND A2a-31 TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
A2a-30	60	240	200	440	930	1175	685	96
	90	240	210	450	970	1135	675	85
	120	240	205	435	860	1050	670	95
	60	260	220	490	1085	1530	740	102
	90	260	220	490	1080	1600	745	100
	120	260	235	510	1085	1745	755	98
	60	280	235	505	1105	1510	710	108
	90	280	280	590	1315	2095	785	108
	120	280	245	555	1220	1960	775	119
A2a-31	60	240	90	185	350	430	695	40
	90	240	105	205	400	535	770	37
	120	240	115	185	365	530	755	41
	60	260	110	235	475	810	810	50
	90	260	110	205	440	780	820	52
	120	260	125	200	430	765	795	50
	60	280	125	200	460	850	810	55
	90	280	135	270	620	1385	865	75
	120	280	130	250	585	1375	860	67

TASK A, Phase 2, Part A (continued)

Samples of three other polymers which have not been evaluated previously were received from Du Pont. These were identified as Neoprene 572, Neoprene 673, and Neoprene 450. Neoprene 572 and Neoprene 673 are types which were, at one time, offered for same but were withdrawn because of lack of interest. Neoprene 450 is the latest addition to the regular line of neoprene latices.

Three compounds, identical in every respect except for the polymer, were prepared; and these formulations are given in Table 9.

Plates were dipped from these compounds according to standard procedure and cured for 60, 90, and 120 minutes at 240°F, 260°F, and 280°F. Physical properties were determined at room temperature and at -40°C, and the results of these tests are given in Tables 10 and 11.

A study of these tables shows that Neoprene 450 is of possible interest for use in meteorological balloons. At all temperatures below 280°F, it has the characteristics of chewing gum with extremely high elongation but very little development of modulus or tensile strength. At 280°F, the modulus is still low; and as the time is increased, there is a very sharp drop in elongation. Elongations at -40°C are poor at all cure temperatures, and the 280°F cures all freeze or show a strong tendency to freeze.

Neoprene 572 has characteristics similar to Neoprene 571 at both room temperature and at -40°C. Since the commercially available polymers have superior properties insofar as meteorological balloon compounds are concerned, there is no reason for conducting any further investigation of this polymer.

Neoprene 673, however, has properties which render its further evaluation desirable. It shows unusually high tensile strength and modulus at room temperature, and these are coupled with relatively high elongation until a curing temperature of 280°F is reached.

Although the low-temperature elongation of Neoprene 673 is somewhat low, the high room-temperature modulus and elongation would permit the use of greater quantities of plasticizer with consequent improvement in low-temperature elongation.

FACTUAL DATA (continued)

TASK A, Phase 2, Part A (continued

TABLE 9

FORMULATIONS OF COMPOUNDS BASED ON VARIOUS NEOPRENE POLYMERS

Formulation No.	A2a-15	A2a-16	A2a-17
Neoprene 572	100.0	-	-
Neoprene 673	-	100.0	-
Neoprene 450	-	-	100.0
Zinc Oxide	5.0	5.0	5.0
Neozone 'D'	2.0	2.0	2.0
N.B.C.	3.0	3.0	3.0
Accelerator 833	1.0	1.0	1.0
Sunaptic Acid	1.0	1.0	1.0
Aquarex SMO	0.5	0.5	0.5
Dibutyl Sebacate	10.0	10.0	10.0

FACTUAL DATA (continued)

TASK A, Phase 2, Part A (continued)

TABLE 10

PHYSICAL PROPERTIES OF COMPOUNDS A2a-15, A2a-16, AND A2a-17 TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A2a-15	30	240	125	185	495	1505	825
	60	240	120	265	830	2050	745
	90	240	125	250	825	1985	735
	30	260	130	250	730	1605	720
	60	260	125	245	790	1770	715
	90	260	135	235	830	1940	720
	30	280	140	255	810	2730	790
	60	280	150	270	725	2440	790
	90	280	180	240	790	2700	790
	120	280	130	265	1160	3175	750
A2a-16	60	240	315	580	1445	4020	960
	90	240	305	640	1435	3780	935
	120	240	310	640	1540	3805	910
	60	260	275	605	1305	3425	945
	90	260	275	600	1315	3490	925
	120	260	225	375	865	2790	900
	60	280	315	745	1625	3035	800
	90	280	310	670	1500	3390	845
	120	280	165	400	895	2100	835
A2a-17	60	240	Modulus and tensile strength too small to read.				
	90	240	" " " " " " " "				
	120	240	" " " " " " " "				
	60	260	Modulus too small to read.			765	>1300*
	90	260	" " " " "			625	>1500*
	120	260	" " " " "			800	>1600*
	60	280	155	185	215	1945	1010
	90	280	130	155	185	1605	1045
	120	280	160	185	220	1625	870

* Extended beyond scale.

FACTUAL DATA (continued)

TASK A, Phase 2, Part A (continued)

TABLE 11

PHYSICAL PROPERTIES OF COMPOUNDS A2a-15, A2a-16, AND A2a-17 TESTED AT -40°C

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A2a-15	30	240	205	765	2725	2725	600
	60	240	190	890	-	2910	580
	90	240	210	925	-	3060	565
	30	260	185	910	2880	3045	615
	60	260	220	995	-	2985	590
	90	260	235	980	-	3140	545
	30	280	220	1065	-	3225	560
	60	280	215	985	-	3115	555
	90	280	240	1105	-	3305	565
	120	280	225	1160	-	3395	540
A2a-16	60	240	675	2595	-	4815	580
	90	240	810	2880	-	4980	565
	120	240	825	2895	-	4325	530
	60	260	790	2765	-	4105	540
	90	260	915	2100	-	4360	570
	120	260	885	2215	-	3590	555
	60	280	1000	2000	-	3200	500
	90	280	670	1970	-	3845	560
	120	280	905	2590	-	3815	540
A2a-17	60	240	795	2180	-	3060	480
	90	240	815	2260	-	3350	500
	120	240	910	2120	-	3215	480
	60	260	825	2390	-	3265	500
	90	260	885	2215	-	3960	460
	120	260	3690	-	-	3690	200
	60	280	3815	-	-	3815	200
	90	280	-	-	-	4695	20
	120	280	-	-	-	4510	0

FACTUAL DATA (continued)

TASK A, Phase 2, Part A (continued)

It appeared possible that a combination of Neoprene 673 and Neoprene 450 might also give desirable characteristics. Accordingly, a compound based on 75 parts of Neoprene 673 and 25 parts of Neoprene 450, having the following formulation and being designated A2a-18, was prepared:

	Compound A2a-18
Neoprene 673	75.0
Neoprene 450	25.0
Zinc Oxide	5.0
Neozone 'D'	2.0
N.B.C.	3.0
Accelerator 833	1.0
Sunaptic Acid	1.0
Aquarex SMO	0.5
Dibutyl Sebacate	10.0

Plates were dipped from this compound according to standard procedure and cured for 60, 90, and 120 minutes at 260°F and 280°F. The cures at 240°F were omitted since it is evident that Neoprene 450 does not cure at this temperature.

Physical properties of this compound were determined at room temperature and at -40°C, and the results of these tests are given in Table 12.

A study of this table shows that the properties of these two types of neoprene are not additive, indicating that the two types are not completely compatible.

As a result of combining the two types, the high tensile strength of Neoprene 673 has been lost, and the high elongation of Neoprene 450 has not been gained. In fact, the elongation of the combination is less than that of Neoprene 673 alone and, of course, much less than that of Neoprene 450.

FACTUAL DATA (continued)

TASK A, Phase 2, Part A (continued)

TABLE 12

PHYSICAL PROPERTIES OF COMPOUND A2a-18
TESTED AT ROOM-TEMPERATURE AND -40°C.

Test Temp. (°C.)	Cure Time (mins)	Cure Temp. (°F.)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
+20	60	260	405	735	1430	2540	790
+20	90	260	420	725	1340	2675	895
+20	120	260	370	640	1270	2240	785
+20	60	280	405	695	1120	2770	775
+20	90	280	385	500	1030	2235	795
+20	120	280	350	530	1090	2285	755
-40	60	260	1520	2890	--	4100	480
-40	90	260	1700	3170	--	4270	440
-40	120	260	1890	3075	--	4320	460
-40	60	280	2245	3080	--	4215	450
-40	90	280	2190	3210	--	4170	450
-40	120	280	2285	3365	--	3890	480

FACTUAL DATA (continued)

TASK A, Phase 2, Part A (continued)

It was considered of value to determine whether an increase in modulus and tensile strength of Neoprene 450 could be obtained by the use of Mistron Vapor without sacrificing the elongation. The following compound, containing Mistron Vapor and identified as A2a-22, was therefore prepared.

	Compound A2a-22
Neoprene 450	100.0
Zinc Oxide	5.0
Neozone 'D'	2.0
N.B.C.	3.0
Accelerator 833	1.0
Sunaptic Acid	1.0
Aquarex SMO	0.5
Dibutyl Sebacate	6.25
Mistron Vapor	20.0

Plates were dipped according to standard procedure and cured for 60, 90, and 120 minutes at 240°F, 260°F, and 280°F. Physical properties were determined at room temperature and at -40°C, and the results of these tests are recorded in Table 13.

A study of these results shows that reinforcement of the film has been achieved by the use of Mistron Vapor. The cures at 260°F show fairly good modulus and tensile strength at room temperature with extremely high elongations. There is a very sharp drop in elongation accompanied by an equally sharp rise in modulus and tensile strength at the 90-minute, 280°F cure. At -40°C, all cures were completely frozen.

The very high room-temperature elongations obtainable with this polymer suggest that further investigations of the effect of increased plasticizer content are indicated.

The unusually high modulus and good elongation obtainable with Neoprene 673 suggested that balloons should be made from a compound based on this polymer. However, considerable difficulties were experienced in obtaining larger quantities of this material since it is made only for special orders. After considerably delay, drum quantities were finally received; and since the original evaluation had been performed on a laboratory sample, and further sample of compound A2a-16 was prepared.

Plates were dipped according to standard procedure, and films were cured for 60, 90, and 120 minutes at 240°F, 260°F, and 280°F. Physical properties were determined at room temperature and at -40°C, and the results of these tests are given in Table 14.

FACTUAL DATA (continued)

TASK A, Phase 2, Part A (continued)

TABLE 13

PHYSICAL PROPERTIES OF COMPOUND A2a-22
TESTED AT ROOM-TEMPERATURE AND -40°C.

Test Temp. (°C.)	Cure Time (mins)	Cure Temp. (°F.)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
+20	60	240	100	105	125	250	2000 +
+20	90	240	95	110	130	320	2000 +
+20	120	240	95	105	120	300	2000 +
+20	60	260	145	190	220	830	1800 +
+20	90	260	180	225	275	1030	1410
+20	120	260	170	205	265	1150	1480
+20	60	280	185	215	260	810	1380
+20	90	280	335	485	720	1380	910
+20	120	280	325	470	680	1370	930
-40	All cure times at all cure temperatures as listed above were frozen.						

FACTUAL DATA (continued)

TASK A, Phase 2, Part A (continued)

TABLE 14

PHYSICAL PROPERTIES OF COMPOUND A2a-16
TESTED AT ROOM TEMPERATURE AND -40°C

Test Temp. (°C)	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
+20	60	240	120	175	370	2100	1100
+20	90	240	110	150	400	1910	1130
+20	120	240	115	160	340	2500	1080
+20	60	260	90	160	400	2020	1110
+20	90	260	90	165	320	2000	1100
+20	120	260	85	140	250	2110	1220
+20	60	280	80	130	250	2590	1070
+20	90	280	85	155	370	2480	990
+20	120	280	90	155	385	3290	1030
-40	60	240	530	1295	2930	4010	700
-40	90	240	465	1205	2965	2965	600
-40	120	240	415	1480	4305	4630	620
-40	60	260	1020	3365	-	3880	460
-40	90	260	755	2125	-	2360	420
-40	120	260	850	2320	-	2815	460
-40	60	280	675	1635	-	2500	480
-40	90	280	725	1775	-	2545	440
-40	120	280	535	1340	-	2275	500

FACTUAL DATA (continued)

TASK A, Phase 2, Part A (continued)

A study of these results shows that this material does not conform to the original sample. The room-temperature elongations are somewhat higher than previously obtained, and the modulus and tensile strength are markedly less than previously obtained.

At -40°C, the elongation is less than previously obtained at all cures except at 240°F. At this temperature, higher elongations are recorded.

It was initially considered that this difference in physical properties was due to the difference between a laboratory batch and a production batch of the polymer. However, it was subsequently determined that upon aging of the film and allowing crystallization to develop, which requires approximately one week, the original physical properties recorded in Table 10 were duplicated.

The evaluation of Neoprene 571 in conjunction with Neoprene 750 was also continued. Replacement of part of the Neoprene 750 in compound A2-9-1 (see Final Report of Contract No. DA-36-039-SC-78239) resulted in a compound identified as A3-31-1 which produced balloons with a much more consistent performance.

Accordingly, three compounds were prepared containing 10, 20, and 30 parts of Neoprene 571, respectively. The formulations of these compounds are given in Table 15.

Plates were dipped from these three compounds according to standard procedure and cured for 60, 90, and 120 minutes at 240°F and 280°F. Physical properties were determined at room temperature, -40°C, and -50°C. The results of these tests are given in Tables 16, 17, and 18.

A study of these tables shows that at room temperature, increasing the amount of Neoprene 571 in the compound has relatively little effect on the physical properties. There is a slight increase in tear strength as the Neoprene 571 ratio is increased and a small but significant loss in elongation. The modulus at 200%, 400%, and 600% elongation is practically unaffected. There is a very small loss in tensile strength with increasing Neoprene 571 content.

All of these compounds are extremely flat during, showing virtually no change in physical characteristics from 90 minutes at 240°F to 120 minutes at 280°F apart from a small loss in modulus at 600% elongation as the proportion of Neoprene 571 is increased.

TABLE 15

FORMULATIONS OF COMPOUNDS CONTAINING INCREASING QUANTITIES OF NEOPRENE 571

Formulation No.	A2a-1	A2a-2	A2a-3
Neoprene 750	90.0	80.0	70.0
Neoprene 571	10.0	20.0	30.0
Zinc Oxide	1.0	1.0	1.0
Neozone 'D'	2.0	2.0	2.0
N.B.C.	3.0	3.0	3.0
Accelerator 833	1.0	1.0	1.0
Sunaptic Acid	1.0	1.0	1.0
Aquarex SMO	0.5	0.5	0.5
Butyl Oleate	10.0	10.0	10.0

FACTUAL DATA (continued)

TASK A, Phase 2, Part A (continued)

TABLE 16

PHYSICAL PROPERTIES OF COMPOUNDS A2a-1, A2a-2, AND A2a-3 TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
A2a-1	60	240	90	135	245	1390	1040	56
	90	240	115	165	275	1695	920	59
	120	240	120	170	300	1725	905	60
	60	260	120	170	230	1355	905	59
	90	260	120	170	230	1545	910	56
	120	260	125	170	230	1330	900	60
	60	280	115	150	210	1395	915	59
	90	280	115	160	225	1735	940	57
	120	280	120	160	225	1770	940	57
A2a-2	60	240	110	160	280	1450	940	54
	90	240	120	165	290	1580	890	60
	120	240	115	160	260	1595	935	57
	60	260	120	165	225	1300	905	58
	90	260	125	170	235	1135	865	58
	120	260	120	165	225	1335	885	57
	60	280	115	160	215	1500	925	54
	90	280	120	160	215	1600	925	55
	120	280	110	155	210	1530	915	57
A2a-3	60	240	105	150	265	1570	1005	55
	90	240	115	165	280	1345	875	58
	120	240	125	175	305	1395	860	60
	60	260	125	170	250	1155	865	60
	90	260	130	165	245	1235	875	56
	120	260	130	175	255	1330	875	67
	60	280	120	165	225	1435	890	58
	90	280	125	165	225	1395	875	67
	120	280	125	165	230	1500	875	62

FACTUAL DATA (*CONTINUED*)

TASK A PHASE 2 PART A (*CONTINUED*)

TABLE 17

PHYSICAL PROPERTIES OF COMPOUNDS A2a-1, A2a-2, and A2a-3 TESTED AT -40°C

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A2a-1	60	240	120	215	910	1930	690
	90	240	170	290	1530	4405	720
	120	240	170	260	1395	3900	730
	60	260	170	280	1940	4270	720
	90	260	165	285	2095	4275	720
	120	260	185	305	2075	4450	720
	60	280	190	335	2305	3610	680
	90	280	195	355	2875	4115	680
	120	280	205	425	2735	4235	660
A2a-2	60	240	145	285	1385	2470	690
	90	240	150	295	1775	3885	720
	120	240	165	280	1720	3490	690
	60	260	165	280	2280	3665	680
	90	260	115	270	2470	4180	680
	120	260	190	365	2660	3985	690
	60	280	190	335	2610	4110	680
	90	280	205	400	2900	4120	670
	120	280	215	400	2685	3695	660
A2a-3	60	240	160	270	1235	2350	700
	90	240	180	305	1680	3520	710
	120	240	190	265	1960	3695	700
	60	260	145	260	2120	4010	700
	90	260	175	345	2590	4145	690
	120	260	175	320	2440	3900	680
	60	280	170	335	2500	4625	700
	90	280	215	470	3095	4525	660
	120	280	220	485	3850	4885	660

FACTUAL DATA (CONTINUED)

TASK A PHASE 2 PART A (CONTINUED)

TABLE 18

PHYSICAL PROPERTIES OF COMPOUNDS A2a-1, A2a-2, and A2a-3
TESTED AT -50°C

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A2a-1	60	240	565	1280	4130	4130	600
	90	240	735	1820	5055	5055	600
	120	240	785	1575	-	5055	590
	60	260	725	1780	-	4535	570
	90	260	945	2255	-	4835	580
	120	260	925	1950	-	4575	570
	60	280	910	2205	-	4765	570
	90	280	1060	2205	-	5230	580
	120	280	1070	2050	-	5145	590
A2a-2	60	240	730	1610	4500	4500	600
	90	240	805	1990	5160	5565	620
	120	240	850	1755	4950	4950	600
	60	260	815	1920	-	4505	570
	90	260	1035	2250	-	4125	550
	120	260	925	2220	-	5255	570
	60	280	875	2220	-	4550	560
	90	280	1070	2170	-	5580	590
	120	280	1045	2170	-	5415	580
A2a-3	60	240	575	1375	-	3870	580
	90	240	815	1800	4805	4805	600
	120	240	825	1860	-	4775	590
	60	260	815	1955	-	4460	550
	90	260	1010	2135	-	4465	560
	120	260	750	2195	-	4890	580
	60	280	895	2160	-	5035	570
	90	280	1030	2220	-	5640	590
	120	280	1295	2470	-	5055	560

TASK A, Phase 2, Part A (continued)

At -40°C there is a slight increase in modulus as the amount of Neoprene 571 in the compound is increased. This is accompanied by a slight fall in elongation. The tensile strength is relatively unaffected. The same pattern is repeated at -50°C.

At both -40°C and -50°C the modulus increases with the state of cure, and the elongation shows a slight drop. Nevertheless, the flat-curing characteristics of these compounds are confirmed by their low-temperature characteristics.

Replacement of part of the Neoprene 750 with Neoprene 571 in a compound in which Dibutyl Sebacate was used as the plasticizer resulted in a very significant increase in modulus (see Contract No. DA-36-039-SC-78239, Task A, Phase 3, Part A).

It may be concluded, therefore, that Butyl Oleate is a much more effective plasticizer for Neoprene 571 than is Dibutyl Sebacate. The type of plasticizer used in high-modulus compounds is thus shown to be of considerable importance, and this must be borne in mind when designing compounds of this type.

Since Neoprene 571 has little value as a polymer for increasing the modulus of compounds in which Butyl Oleate is the plasticizer, it was decided to investigate the possibilities of using Neoprene 400 for this purpose.

Six compounds containing varying blends of Neoprene 750, Neoprene 400, and Butyl Oleate were prepared. The formulations of these compounds are given in Table 19.

Plates were dipped from these compounds according to standard procedure and cured for 60, 90, and 120 minutes at 240°F, 260°F, and 280°F. Physical characteristics were determined at room temperature and at -40°C. The physical characteristics of A2a-23 and A2a-26 were also determined at -50°C. The results of these tests are given in Tables 20, 21, and 22.

A study of these results shows that at room temperature, Neoprene 400 has little effect on modulus when 20 parts are used. Forty parts of Neoprene 400 results in a sharp increase in modulus which is accompanied by a significant reduction in elongation. The elongation, however, is still satisfactory. This is true whether 5 parts of 10 parts of Butyl Oleate are used.

FACTUAL DATA (continued)

TASK A, Phase 2, Part A (continued)

TABLE 19

FORMULATIONS OF COMPOUNDS CONTAINING VARYING QUANTITIES OF NEOPRENE 400

Formulation No.	A2a-21	A2a-22	A2a-23	A2a-24	A2a-25	A2a-26
Neoprene 750	100.0	80.0	60.0	100.0	80.0	60.0
Neoprene 400	-	20.0	40.0	-	20.0	40.0
Zinc Oxide	5.0	5.0	5.0	5.0	5.0	5.0
Neozone 'D'	2.0	2.0	2.0	2.0	2.0	2.0
N.B.C.	3.0	3.0	3.0	3.0	3.0	3.0
Accelerator 833	1.0	1.0	1.0	1.0	1.0	1.0
Sunaptic Acid	1.0	1.0	1.0	1.0	1.0	1.0
Aquarex SMO	0.5	0.5	0.5	0.5	0.5	0.5
Butyl Oleate	5.0	5.0	5.0	10.0	10.0	10.0

TABLE 20

PHYSICAL PROPERTIES OF COMPOUNDS A2a-21, A2a-22, A2a-23, A2a-24, A2a-25, AND A2a-26 TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
A2a-21	60	240	90	135	220	2010	1250	72
	90	240	94	140	235	1970	1330	74
	120	240	105	155	230	1950	1265	73
	60	260	125	160	225	2420	1215	75
	90	260	135	165	220	2245	1190	77
	120	260	140	170	255	1970	1020	69
	60	280	140	175	225	2205	1030	80
	90	280	145	170	230	2295	1025	84
	120	280	140	165	255	2150	950	85
A2a-22	60	240	115	155	260	1560	1160	70
	90	240	125	175	260	1470	1120	70
	120	240	130	165	280	1740	1100	75
	60	260	120	160	255	1750	1060	68
	90	260	125	160	260	1780	965	78
	120	260	120	160	260	1825	955	82
	60	280	145	180	270	1875	970	79
	90	280	140	160	270	1835	960	83
	120	280	150	165	305	2100	925	80
A2a-23	60	240	190	290	575	1910	1005	54
	90	240	185	300	610	1800	960	55
	120	240	190	300	630	1910	955	54
	60	260	170	270	595	1990	960	100
	90	260	170	310	655	2240	960	113
	120	260	170	230	520	1990	960	100
	60	280	165	230	515	2050	1000	68
	90	280	165	255	505	1985	1010	78
	120	280	150	190	435	2125	965	91
A2a-24	60	240	95	140	200	1275	1150	47
	90	240	110	145	185	1535	1110	58
	120	240	105	145	200	1490	1100	63
	60	260	110	135	190	1478	1020	60
	90	260	105	145	215	1540	965	60
	120	260	110	145	215	1655	950	57
	60	280	120	150	215	1950	1040	68
	90	280	130	170	220	1800	970	69
	120	280	135	155	225	2035	970	70
A2a-25	60	240	100	135	235	1270	1055	50
	90	240	105	135	170	1270	1070	49
	120	240	110	135	210	1285	1070	56
	60	260	115	145	205	1645	1040	55
	90	260	110	130	225	1345	960	55
	120	260	110	145	240	1445	940	56
	60	280	120	155	250	1640	950	58
	90	280	110	150	200	1445	950	58
	120	280	115	140	220	1795	950	58
A2a-26	60	240	85	120	235	1260	1080	54
	90	240	170	290	590	1655	910	81
	120	240	180	275	610	1660	885	100
	60	260	160	260	610	1725	890	90
	90	260	160	245	600	1585	845	93
	120	260	160	260	645	1740	840	85
	60	280	190	285	645	2000	890	88
	90	280	175	280	650	2075	890	102
	120	280	155	250	620	2080	875	100

TABLE 21

PHYSICAL PROPERTIES OF COMPOUNDS A2a-21, A2a-22, A2a-23, A2a-24, A2a-25, AND A2a-26 TESTED AT -40°C

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A2a-21	60	240	200	470	2215	2900	650
	90	240	190	390	1775	2960	700
	120	240	130	305	1590	2590	670
	60	260	180	335	2110	3870	700
	90	260	200	415	2555	4085	660
	120	260	200	390	2780	4085	670
	60	280	195	360	2525	3205	650
	90	280	185	340	2265	4345	700
	120	280	210	430	3310	4345	650
A2a-22	60	240	420	1375	3800	4210	620
	90	240	430	1350	4070	4215	610
	120	240	450	1325	4000	4480	530
	60	260	475	1420	4590	5025	630
	90	260	450	1420	4265	5275	650
	120	260	490	1445	4690	5235	640
	60	280	520	1645	4860	5880	660
	90	280	495	1540	4670	5355	630
	120	280	655	1685	-	5330	590
A2a-23	60	240	1480	2935	-	4975	560
	90	240	1450	3015	-	4880	540
	120	240	1395	2885	-	5105	560
	60	260	1250	2975	-	5300	560
	90	260	1260	2850	-	5065	560
	120	260	1360	2990	-	5025	550
	60	280	1555	3250	-	5585	550
	90	280	1430	3155	-	5750	560
	120	280	1545	3390	-	4980	510
A2a-24	60	240	115	165	750	2480	770
	90	240	115	170	810	3405	800
	120	240	125	180	825	3125	790
	60	260	125	175	875	3020	770
	90	260	120	175	790	2460	740
	120	260	130	195	1105	3085	750
	60	280	135	210	1070	3075	730
	90	280	125	185	1015	3735	760
	120	280	145	230	1340	3950	740
A2a-25	60	240	240	715	2715	3500	660
	90	240	245	770	2710	3595	660
	120	240	300	850	3085	3910	670
	60	260	315	905	3285	4305	660
	90	260	340	800	3140	4390	680
	120	260	320	940	3465	4360	660
	60	280	435	1145	3905	4475	640
	90	280	410	1095	4005	4745	650
	120	280	420	1120	4065	4625	630
A2a-26	60	240	525	1580	-	3425	570
	90	240	625	1990	-	4215	590
	120	240	610	1900	4295	4680	620
	60	260	680	1955	4570	4705	610
	90	260	740	1875	4930	4930	600
	120	260	770	1870	4955	5120	610
	60	280	1000	2430	-	5190	580
	90	280	675	1875	4590	5315	640
	120	280	900	2455	5830	5830	600

FACTUAL DATA (continued)

TASK A, Phase 2, Part A (continued)

TABLE 22

PHYSICAL PROPERTIES OF COMPOUNDS A2a-23 AND A2a-26
TESTED AT -50°C.

Compound No.	Cure Time (mins)	Cure Temp. (°F.)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A2a-23	60	240	2675	4410	-	5790	500
	90	240	2675	4330	-	4905	430
	120	240	2605	4320	-	5340	500
	60	260	2805	4255	-	4845	450
	90	260	2475	4280	-	5470	470
	120	260	2770	4510	-	5515	460
	60	280	2935	4590	-	6080	490
	90	280	2800	4530	-	6070	490
	120	280	2835	4790	-	5815	460
A2a-26	60	240	1665	3380	-	4830	500
	90	240	1760	3380	-	4805	490
	120	240	1635	3435	-	5200	520
	60	260	1775	3415	-	5755	530
	90	260	1525	3505	-	5215	530
	120	260	1595	3545	-	5330	520
	60	280	1870	3875	-	5850	530
	90	280	1905	3865	-	6215	550
	120	280	2085	4070	-	5930	510

FACTUAL DATA (continued)

TASK A, Phase 2, Part A (continued)

At -40°C a marked increase in modulus is shown when 20 parts of Neoprene 400 are used, and there is a further comparable increase in modulus when the Neoprene 400 content is raised to 40 parts.

When 5 parts of Butyl Oleate are used, there is relatively little change in elongation with the use of 20 parts of Neoprene 400, and a noticeable drop in elongation when 40 parts are added. In the compounds containing 10 parts of Butyl Oleate, there is a significant loss in elongation on the addition of 20 parts of Neoprene 400, and a relatively slight additional loss in elongation when 40 parts of Neoprene 400 are used.

Since 40 parts of Neoprene 400 are required to affect the room-temperature modulus, only compounds A2a-23 and A2a-26 were evaluated at -50°C. Both of these compounds showed satisfactory elongations at this temperature, A2a-26 being somewhat superior and having substantially lower modulus as would be expected.

A study of the effect of aging neoprene latex and neoprene latex compounds was conducted. Two series of tests were run, the procedure in each case being the same. A drum of Neoprene 750 and one of Neoprene 571 were set aside as soon as received, and a sample of compound A3-105 was prepared from the fresh latex. In one series, additional batches of the same compound were prepared at 15-day intervals, and in the second series batches were prepared at 30-day intervals. The first series was continued for 75 days, and the second series for 180 days.

Plates were dipped from the fresh compound and also from all previously made compounds each time a fresh compound was prepared. They were cured for 60, 90, and 120 minutes at 280°F, and the physical properties of the films were determined at room temperature. The results of these tests are given in Tables 23 and 24.

In the first series of tests, fresh latex compounded immediately did not develop its potential tensile strength until a period of 60 to 75 days had elapsed. If the latex had been aged for 30 days prior to compounding, then the maximum tensile strength was developed immediately. Aging the latex had virtually no effect on the modulus and elongation, but aging of the compound resulted in an increase in modulus and a relatively small drop in elongation.

TABLE 23

EFFECT OF AGING NEOPRENE LATEX AND NEOPRENE LATEX COMPOUNDS ON PHYSICAL PROPERTIES OF CURED FILMS

Latex Age before Compound.	Comp. Age before Dipping	Cure (min. @ 280°C)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
Fresh	Fresh	60	140	170	300	1950	940	74
		90	145	185	300	2025	910	71
		120	150	190	305	2085	905	71
Fresh	30 days	60	135	180	250	1535	895	75
		90	130	170	265	1845	935	67
		120	140	175	260	1820	925	64
Fresh	45 days	60	155	215	420	2150	835	70
		90	160	215	440	2395	845	63
		120	165	235	490	2305	830	78
Fresh	60 days	60	145	190	300	2245	915	80
		90	140	185	300	2430	925	69
		120	140	195	320	2380	905	67
Fresh	75 days	60	165	200	375	2850	950	89
		90	180	210	405	2835	915	89
		120	190	225	495	2680	865	87
30 days	Fresh	60	145	185	310	2885	975	89
		90	150	190	320	2945	985	75
		120	155	210	365	2490	935	93
30 days	15 days	60	145	200	365	1995	865	65
		90	150	220	360	2080	865	71
		120	160	215	485	2210	825	78
30 days	30 days	60	140	185	310	2135	900	63
		90	150	200	340	2300	895	72
		120	155	205	355	2605	890	73
30 days	45 days	60	185	215	415	2785	915	86
		90	185	215	450	2705	895	88
		120	195	225	470	2855	880	86
45 days	Fresh	60	140	190	325	2230	920	69
		90	140	195	345	2460	915	73
		120	155	205	445	2520	880	74
45 days	15 days	60	145	195	310	2480	915	67
		90	140	190	305	2420	895	72
		120	145	195	335	2470	905	75
45 days	30 days	60	195	230	465	3195	920	84
		90	180	210	420	3050	920	81
		120	180	225	505	3120	895	80
60 days	Fresh	60	150	195	315	2435	935	71
		90	150	200	325	2240	900	74
		120	150	195	355	2365	885	73
60 days	15 days	60	180	210	405	3015	935	86
		90	185	215	435	3035	915	83
		120	190	225	495	2740	875	80
75 days	Fresh	60	175	205	390	2970	945	80
		90	185	220	470	2785	895	78
		120	180	220	465	3110	915	88

TABLE 24

EFFECT OF AGING NEOPRENE LATEX AND NEOPRENE LATEX COMPOUNDS ON PHYSICAL PROPERTIES OF CURED FILMS

Latex Age before Compound.	Comp. Age before Dipping	Cure (min. @ 280°C	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
Fresh	Fresh	60	165	200	320	2700	930	85
		90	165	200	350	2715	905	70
		120	170	200	385	2665	890	85
Fresh	30 days	60	180	220	490	2795	865	75
		90	165	210	450	2550	860	70
		120	195	235	655	2570	805	75
Fresh	60 days	60	145	200	340	2400	895	80
		90	160	185	370	2280	880	85
		120	155	210	480	2630	875	75
Fresh	120 days	60	125	185	350	2260	885	-
		90	115	160	390	2635	875	-
		120	100	170	395	2595	855	-
Fresh	150 days	60	105	160	315	2275	890	-
		90	85	170	385	2130	845	-
		120	110	195	535	2695	825	-
Fresh	180 days	60	165	200	395	2370	865	70
		90	145	190	385	2350	845	75
		120	100	175	420	2385	860	75
30 days	Fresh	60	175	210	415	2680	875	90
		90	170	200	400	2910	910	95
		120	180	220	520	2540	845	80
30 days	30 days	60	115	195	350	2390	875	85
		90	130	170	385	2425	875	80
		120	130	195	415	2375	850	80
30 days	90 days	60	100	165	330	2090	870	-
		90	130	170	410	2410	855	-
		120	120	165	410	2480	865	-
30 days	120 days	60	115	155	310	2435	900	-
		90	90	180	405	2345	865	-
		120	100	170	515	2560	845	-
30 days	150 days	60	145	200	370	2230	855	71
		90	150	200	390	2395	860	80
		120	145	200	400	2230	830	80

FACTUAL DATA (continued)

TASK A, Phase 2, Part A (continued)

TABLE 24 (continued)

Latex Age before Compound.	Comp. Age before Dipping	Cure (min. @ 280°C)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
60 days	Fresh	60 90 120	155 130 135	190 175 200	385 390 400	2820 2795 2615	925 975 875	85 90 85
60 days	60 days	60 90 120	115 125 115	150 165 170	355 415 400	2545 2400 2555	905 855 885	- - -
60 days	90 days	60 90 120	95 90 95	180 185 190	360 370 445	2665 2385 2395	900 850 820	- - -
60 days	120 days	60 90 120	125 150 150	200 210 200	350 405 425	2460 2370 2360	895 865 855	65 65 80
120 days	Fresh	60 90 120	125 150 145	165 190 195	375 400 360	2475 2930 2930	910 920 915	- - -
120 days	30 days	60 90 120	90 90 85	150 180 170	300 330 370	2355 2310 2090	915 895 860	- - -
120 days	60 days	60 90 120	145 135 150	205 185 200	380 380 420	2440 2265 2440	870 860 855	80 85 80
150 days	Fresh	60 90 120	85 90 90	165 180 200	375 360 430	2160 2580 2500	870 880 865	- - -
150 days	30 days	60 90 120	155 135 145	205 190 195	505 405 405	2585 2110 2510	835 835 875	75 65 70
180 days	Fresh	60 90 120	155 150 150	205 195 200	385 355 415	2525 2310 2620	895 885 895	75 75 80

FACTUAL DATA (continued)

TASK A, Phase 2, Part A (continued)

In the second series, there is little change in tensile strength as compound or latex ages. There does, however, appear to be less consistency in the tensile strength from test to test as the compound or the raw latex becomes older.

There is a steady decline in elongation as the compound ages, but this is much less marked when the raw latex is aged. The decline in elongation is, however, noticeably more rapid when the compound is made from aged latex with the result that the elongations at the conclusion of the test are generally comparable regardless of whether or not the latex or the compound is aged.

The 400% and 600% modulus results show relatively little change, the 600% modulus tending to increase slightly as either latex or compound becomes older. The 200% modulus, however, decreases steadily and markedly as either the latex or the compound ages.

It would appear from this study that there are no advantages to aging either neoprene latex or neoprene latex compounds. At the same time, there is no serious loss in physical characteristics if the latex or the compound is not more than 60 days old before being used.

The difference between the two series, however, do indicate that there are intrinsic variations in the neoprene polymers themselves.

Part B: Plasticizers

As a result of the plasticizer study carried out in a previous contract, it was shown that Butyl Oleate gave the best low-temperature physical characteristics. However, previous work was restricted to the use of a single plasticizer in the compound, and it has been felt for some time that better results might be obtained from a combination of two or more plasticizers in the same compound. Inquiries throughout the industry indicated that little, if any work had been conducted along these lines.

The number of such combinations is almost infinite, and it was decided to conduct a preliminary study using two plasticizers in varying proportions. Butyl Oleate and Dibutyl Sebacate were selected, the former, as already stated, being generally regarded as the best low-temperature plasticizer widely used in conjunction with neoprene and also giving excellent low-temperature properties.

FACTUAL DATA (continued)

TASK A, Phase 2, Part B (continued)

Five compounds containing varying proportions of Butyl Oleate and Dibutyl Sebacate were prepared. The formulations of these compounds are given in Table 25.

Plates were dipped from the above compounds according to standard procedure and cured for 40, 60, and 80 minutes at 240°F, 260°F, and 280°F. Physical properties were determined at room temperature, -70°C, and -75°C. The results of these tests are given in Tables 26, 27, and 28.

A study of the results at room temperature shows that the replacement of Dibutyl Sebacate with Butyl Oleate results in a gradually falling modulus at high curing temperatures. However, at low and intermediate curing temperatures, there is little change in modulus.

It is interesting to note that the highest modulus figures are obtained with compounds A2b-1 and A2b-6, neither of which contain a blend of plasticizer. Increasing the Butyl Oleate ratio shows some improvement in room-temperature elongation and has virtually no effect on tensile strength.

At -70°C, there is a steady improvement in low-temperature characteristics as the Butyl Oleate content increases up to 60%. Compound A2b-4, containing 60% Butyl Oleate, and compound A2b-5, containing 80% Butyl Oleate, have almost identical properties and are both superior to A2b-6 which contains 100% Butyl Oleate.

Compound A2b-5 shows a distinct superiority to any other compound tested at -75°C. The sample cured for 40 minutes at 260°F has an elongation of 510% and shows no signs of cold flow. A2b-4 is almost as good but is, nevertheless, inferior.

It would appear that an improvement in low-temperature characteristics can be secured by blending plasticizers. Therefore, it was decided to evaluate blends of other types of plasticizers which by themselves showed good low-temperature characteristics.

The original plasticizer study conducted during Contract No. DA-36-039-SC-72386 had shown that KP-90 (an epoxy stearate) and DOZ-9057 (an azelate) were both capable of producing films with good low-temperature characteristics, being superior to Dibutyl Sebacate but inferior to Butyl Oleate.

TABLE 25

FORMULATIONS CONTAINING VARYING PROPORTIONS OF BUTYL OLEATE AND DIBUTYL SEBACATE

Formulation No.	A2b-1	A2b-2	A2b-3	A2b-4	A2b-5	A2b-6
Neoprene 750	80.0	80.0	80.0	80.0	80.0	80.0
Neoprene 735	10.0	10.0	10.0	10.0	10.0	10.0
Neoprene 571	10.0	10.0	10.0	10.0	10.0	10.0
Zinc Oxide	2.5	2.5	2.5	2.5	2.5	2.5
Neozone 'D'	2.0	2.0	2.0	2.0	2.0	2.0
N.B.C.	3.0	3.0	3.0	3.0	3.0	3.0
Accelerator 833	1.0	1.0	1.0	1.0	1.0	1.0
Sunaptic Acid	1.0	1.0	1.0	1.0	1.0	1.0
Aquarex SMO	0.5	0.5	0.5	0.5	0.5	0.5
Sulphur	3.0	3.0	3.0	3.0	3.0	3.0
Dibutyl Sebacate	25.0	20.0	15.0	10.0	5.0	-
Butyl Oleate	-	5.0	10.0	15.0	20.0	25.0

TABLE 26

PHYSICAL PROPERTIES OF COMPOUNDS A2b-1, A2b-2, A2b-3, A2b-4, A2b-5 AND A2b-6 TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F.)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
A2b-1	40	240	50	85	180	555	915	32
	60	240	65	105	195	845	970	37
	80	240	90	135	210	1215	925	43
	40	260	80	130	215	960	905	44
	60	260	110	150	320	1400	795	45
	80	260	120	170	395	1390	755	51
	40	280	115	165	325	1255	775	49
	60	280	125	175	400	1425	760	59
	80	280	135	200	670	1375	685	58
A2b-2	40	240	50	95	185	540	860	29
	60	240	75	120	205	935	955	43
	80	240	85	125	195	1100	950	40
	40	260	75	115	185	900	940	46
	60	260	105	160	245	1480	855	53
	80	260	110	160	315	1545	815	57
	40	280	120	170	340	1595	810	61
	60	280	115	160	285	1465	825	64
	80	280	130	190	510	1385	715	60
A2b-3	40	240	50	95	190	485	835	30
	60	240	70	110	205	820	910	38
	80	240	80	125	205	1150	925	45
	40	260	75	115	190	960	960	43
	60	260	105	160	280	1280	815	56
	80	260	115	165	315	1370	785	51
	40	280	120	180	340	1600	805	54
	60	280	115	180	325	1325	780	50
	80	280	130	195	485	1380	730	58
A2b-4	40	240	40	75	180	585	940	21
	60	240	55	90	185	735	960	33
	80	240	70	105	175	1055	990	39
	40	260	65	105	180	595	865	39
	60	260	100	155	265	1535	845	51
	80	260	105	155	280	1505	840	57
	40	280	105	155	230	1330	865	61
	60	280	110	150	250	1635	875	64
	80	280	125	180	385	1425	745	54
A2b-5	40	240	45	70	175	520	930	27
	60	240	55	100	190	875	1000	34
	80	240	70	110	185	1050	990	41
	40	260	80	120	175	1225	965	40
	60	260	100	140	225	1405	875	41
	80	260	100	150	275	1410	835	52
	40	280	100	150	275	1685	855	47
	60	280	95	145	250	1445	850	51
	80	280	105	155	370	1540	775	42
A2b-6	40	240	75	200	470	890	860	37
	60	240	70	170	415	1060	900	39
	80	240	75	180	420	1080	935	39
	40	260	70	180	425	935	865	48
	60	260	90	165	350	1610	1045	35
	80	260	80	145	330	1505	1015	39

TABLE 27

PHYSICAL PROPERTIES OF COMPOUNDS A2b-1, A2b-2, A2b-3, A2b-4, A2b-5 AND A2b-6 TESTED AT -70°C.

Compound No.	Cure Time (mins)	Cure Temp. (°F.)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Remarks
A2b-1	40	240	1905	3145	-	4020	470	cold flow
	60	240	1740	3040	-	3845	480	cold flow
	80	240	2285	3510	-	4045	450	cold flow
	40	260	-	-	-	2172	60	frozen
	60	260	-	-	-	2716	80	frozen
	80	260	-	-	-	3125	0	frozen
	40	280	2025	4330	-	5340	480	cold flow
	60	280	-	-	-	2850	0	frozen
	80	280	-	-	-	3725	0	frozen
A2b-2	40	240	1855	3190	-	4140	500	cold flow
	60	240	1865	3045	-	4340	490	cold flow
	80	240	1990	2960	-	3625	440	cold flow
	40	260	2140	3470	-	4670	510	cold flow
	60	260	2240	3610	-	5095	490	cold flow
	80	260	-	-	-	2930	0	frozen
	40	280	2505	3915	-	4580	410	cold flow
	60	280	-	-	-	2715	40	frozen
	80	280	-	-	-	3285	0	frozen
A2b-3	40	240	1475	2900	-	4100	520	
	60	240	1740	3145	-	3950	480	
	80	240	1945	2985	-	4075	480	cold flow
	40	260	2290	3365	-	4790	510	cold flow
	60	260	2420	4105	-	4810	450	cold flow
	80	260	-	-	-	3720	0	frozen
	40	280	2735	-	-	4145	390	cold flow
	60	280	2440	3625	-	4600	460	cold flow
	80	280	-	-	-	3625	60	frozen
A2b-4	40	240	1300	2645	-	3570	500	
	60	240	1380	2720	-	3970	530	
	80	240	1555	3010	-	3515	480	
	40	260	1670	2970	-	3230	430	
	60	260	2220	3970	-	4600	480	cold flow
	80	260	1450	2905	-	4785	520	cold flow
	40	280	2125	3620	-	4235	460	cold flow
	60	280	2258	3610	-	4995	490	cold flow
	80	280	-	-	-	3275	40	frozen
A2b-5	40	240	1260	2500	-	3815	510	
	60	240	1310	3720	-	4755	510	
	80	240	1520	2945	-	4225	510	
	40	260	1675	3000	-	3740	480	
	60	260	2030	3515	-	4660	490	cold flow
	80	260	1880	3740	-	4695	490	cold flow
	40	280	2180	3570	-	4225	460	cold flow
	60	280	1930	3320	-	4325	490	cold flow
	80	280	-		-	3225	40	frozen
A2b-6	40	240	2565	3855	-	4310	430	cold flow
	60	240	2630	3485	-	4080	450	cold flow
	80	240	2095	3550	-	4265	470	
	40	260	2115	3365	-	4205	470	
	60	260	-	-	-	3995	0	frozen
	80	260	-	-	-	3350	0	frozen

TABLE 28

PHYSICAL PROPERTIES OF COMPOUNDS A2b-1, A2b-2, A2b-3, A2b-4, A2b-5, AND A2b-6 TESTED AT -75°C

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Remarks
A2b-1	not tested - showed cold flow or froze at all cures at -70°C							
A2b-2	not tested - showed cold flow or froze at all cures at -70°C							
A2b-3	40	240	-	-	-	2715	80	frozen
	60	240	-	-	-	2970	0	frozen
	other cures not tested - showed cold flow or froze at -70°C							
A2b-4	40	240	2010	3450	-	3450	400	cold flow
	60	240	-	-	-	3610	80	frozen
	80	240	2210	3740	-	4190	450	cold flow
	40	260	2325	3575	-	4800	490	cold flow
	other cures not tested - showed cold flow or froze at -70°C							
A2b-5	40	240	2045	3190	-	4065	470	cold flow
	60	240	1465	3435	-	3765	440	cold flow
	80	240	1975	3450	-	4605	470	cold flow
	40	260	2030	3860	-	4920	510	
	other cures not tested - showed cold flow or froze at -70°C							
A2b-6	80	240	-	-	-	3410	20	frozen
	40	260	-	-	-	2930	20	frozen
	other cures not tested - showed cold flow or froze at -70°C							

FACTUAL DATA (continued)

TASK A, Phase 2, Part B (continued)

Accordingly, a series of compounds was prepared with blends of KP-90 and Butyl Oleate, and DOZ-9057 and Butyl Oleate. The formulations of these compounds are given in Table 29. One compound containing 100% Butyl Oleate was used as a control

Plates were dipped according to standard procedure and cured for 40, 60, and 80 minutes at 240°F, 260°F, and 280°F. Physical characteristics were determined at room temperature, at -70°C, and at -75°C in those cases where there was no cold flow or freezing at -70°C . The results of these tests are given in Tables 30 through 35.

A study of these results shows some interesting features. Compound A2b-6 shows better results than it did in the previous test series where blends of Butyl Oleate and Dibutyl Sebacate were being examined. At the time the previous series was being evaluated, the cold box was not functioning correctly and was being supplemented with dry ice. It would appear that this method of operation is more severe than standard operations of the box using the refrigeration equipment only.

Blending Butyl Oleate with KP-90 shows no unexpected results. The effects of the two plasticizers seem to be additive, and the low-temperature characteristics of the compound deteriorate as the amount of KP-90 increases.

Compound A2b-6 containing 100% Butyl Oleate has the best properties; compound A2b-10 containing 100% KP-90 has the poorest properties.

However, blending Butyl Oleate with DOZ-9057 shows some unexpected results. Increasing the proportion of DOZ-9057 results in higher room-temperature modulus and lower room-temperature elongation

At -70°C, increasing the DOZ-9057 results in poorer plysical characteristics when a curing temperature of 240°F is used. When cured at 260°F, the physical properties pass through a minimum at the 25 parts Butyl Oleate/75 parts DOZ-9057 compound, the compound containing only DOZ-9057 being superior. When cured at 280°F, the compound containing only DOZ-9057 is also superior.

It seems that, whereas blending Butyl Oleate and Dibutyl Sebacate results in an improvement above either plasticizer individually, blends of Butyl Oleate and DOZ-9057 are inferior to either one used by itself.

TABLE 29

FORMULATIONS OF COMPOUNDS CONTAINING BLENDS OF PLASTICIZERS

Formulation No.	A2b-6	A2b-7	A2b-8	A2b-9	A2b-10	A2b-11	A2b-12	A2b-13	A2b-14
Neoprene 750	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00
Neoprene 735	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Neoprene 571	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Zinc Oxide	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Neozone 'D'	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
N.B.C.	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Accelerator 833	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Sunaptic Acid	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Aquarex SMO	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Sulphur	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Butyl Oleate	25.00	18.75	12.50	6.25	-	18.75	12.50	6.25	-
K.P. 90	-	6.25	12.50	18.75	25.00	-	-	-	-
DOZ 9057	-	-	-	-	-	6.25	12.50	18.75	25.00

TABLE 30

PHYSICAL PROPERTIES OF COMPOUNDS A2b-6, A2b-7, A2b-8, A2b-9, AND A2b-10 TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
A2b-6	40	240	60	105	225	740	905	35
	60	240	90	130	235	1070	865	41
	80	240	85	135	235	1065	875	46
	40	260	75	120	200	1110	930	43
	60	260	90	135	245	1060	805	41
	80	260	95	140	260	1320	825	41
	40	280	95	140	270	1230	820	45
	60	280	90	140	250	1265	830	41
	80	280	95	140	245	1255	815	44
A2b-7	40	240	45	85	185	490	855	27
	60	240	70	105	185	855	960	44
	80	240	70	105	185	1090	995	39
	40	260	70	115	190	925	960	41
	60	260	85	120	180	1200	965	47
	80	260	85	125	200	1290	900	44
	40	280	80	115	175	1230	980	43
	60	280	90	130	200	1490	920	45
	80	280	90	135	235	1425	880	45
A2b-8	40	240	55	100	215	675	925	40
	60	240	65	105	205	890	945	37
	80	240	75	110	180	1070	955	48
	40	260	70	110	195	940	965	43
	60	260	75	110	180	1060	955	43
	80	260	85	125	185	1260	925	47
	40	280	80	120	190	1060	930	47
	60	280	90	135	215	1325	890	45
	80	280	80	135	235	1195	835	51
A2b-9	40	240	50	90	205	490	850	35
	60	240	65	105	200	730	925	38
	80	240	75	110	180	955	960	38
	40	260	75	105	180	970	985	41
	60	260	75	110	175	1105	975	43
	80	260	80	120	180	1235	940	49
	40	280	80	120	185	1060	945	42
	60	280	85	125	180	1495	950	44
	80	280	90	135	225	1495	885	45
A2b-10	40	240	55	110	225	480	810	27
	60	240	60	110	210	775	925	43
	80	240	80	115	195	995	955	44
	40	260	70	125	215	810	905	38
	60	260	75	115	180	1025	950	43
	80	260	90	130	190	1285	945	42
	40	280	70	115	175	1050	940	42
	60	280	85	125	200	1345	925	46
	80	280	95	140	245	1395	865	49

TABLE 33

PHYSICAL PROPERTIES OF COMPOUNDS A2b-6, A2b-11, A2b-12, A2b-13, AND A2b-14 TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
A2b-6	40	240	60	105	225	740	905	35
	60	240	90	130	235	1070	865	41
	80	240	85	135	235	1065	875	46
	40	260	75	120	200	1110	930	43
	60	260	90	135	245	1060	805	41
	80	260	95	140	260	1320	825	41
	40	280	95	140	270	1230	820	45
	60	280	90	140	250	1265	830	41
	80	280	95	140	245	1255	815	44
A2b-11	40	240	60	105	215	750	915	40
	60	240	75	115	210	950	925	46
	80	240	105	155	310	1230	800	50
	40	260	95	130	210	1115	905	44
	60	260	100	155	285	1220	800	43
	80	260	100	155	270	1120	785	43
	40	280	95	150	265	1045	795	44
	60	280	95	145	255	1295	830	45
	80	280	95	140	250	1255	820	48
A2b-12	40	240	55	95	210	545	865	30
	60	240	65	110	210	775	915	38
	80	240	95	130	230	1035	870	48
	40	260	85	130	245	930	900	39
	60	260	100	145	255	1175	840	53
	80	260	100	165	330	1190	765	43
	40	280	95	140	225	1090	855	79
	60	280	105	160	270	1250	805	44
	80	280	100	155	310	1180	775	48
A2b-13	40	240	60	110	225	680	895	36
	60	240	70	125	235	845	905	42
	80	240	100	145	265	1055	845	49
	40	260	95	145	280	1145	835	52
	60	260	110	160	335	1115	765	42
	80	260	110	170	360	1135	750	43
	40	280	100	150	285	990	790	41
	60	280	110	160	360	1160	765	49
	80	280	105	165	380	1220	745	43
A2b-14	40	240	70	115	250	670	865	36
	60	240	70	120	250	815	910	42
	80	240	105	155	310	1145	795	47
	40	260	85	140	250	865	830	43
	60	260	115	170	390	1080	735	50
	80	260	115	175	465	1225	725	45
	40	280	115	170	395	1080	725	35
	60	280	115	175	475	1095	695	47
	80	280	115	180	555	1255	695	41

FACTUAL DATA (*CONTINUED*)

TASK A PHASE 2 PART B (*CONTINUED*)

TABLE 32

PHYSICAL PROPERTIES OF COMPOUNDS A2b-6, A2b-7, A2b-8, A2b-9, AND A2b-10 TESTED AT -70°C

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Remarks
A2b-6	40	240	1170	2290	-	4270	570	
	60	240	1205	2560	-	4655	570	
	80	240	1285	2525	-	3645	500	
	40	260	1440	2690	-	4085	510	
	60	260	1675	3295	-	4505	520	
	80	260	2220	3710	-	4870	490	cold flow
	40	280	2105	3650	-	5370	520	
	60	280	1995	3625	-	4335	460	
	80	280	2615	3605	-	4595	460	cold flow
A2b-7	40	240	1445	2650	-	3940	520	
	60	240	1450	2770	-	3700	480	
	80	240	1390	2565	-	3705	490	
	40	260	1835	2960	-	4140	500	
	60	260	2100	3365	-	4935	510	cold flow
	80	260	2450	3425	-	4230	470	cold flow
	40	280	2315	3595	-	4595	500	cold flow
	60	280	2420	3765	-	4860	460	cold flow
	80	280	2065	3675	-	4910	500	cold flow
A2b-8	40	240	1440	2630	-	3485	500	
	60	240	-	-	-	2665	160	cold flow
	80	240	-	-	-	2815	0	frozen
	40	260	2405	3170	-	4565	510	cold flow
	60	260	2095	3000	-	4345	520	cold flow
	80	260	-	-	-	2845	20	frozen
	40	280	-	-	-	2500	0	frozen
	60	280	-	-	-	3290	80	frozen
	80	280	-	-	-	2955	0	frozen
A2b-9	40	240	1970	2900	-	3405	450	cold flow
	60	240	-	-	-	2620	40	frozen
	80	240	-	-	-	2500	0	frozen
	All remaining cures were frozen.							
A2b-10	All cures were frozen.							

TABLE 33

PHYSICAL PROPERTIES OF COMPOUNDS A2b-6, A2b-11, A2b-12, A2b-13, AND A2b-14 TESTED AT -70°C

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Remarks
A2b-6	40	240	1170	2290	-	4270	570	
	60	240	1205	2560	-	4655	570	
	80	240	1285	2525	-	3645	500	
	40	260	1440	2690	-	4085	510	
	60	260	1675	3295	-	4505	520	
	80	260	2220	3710	-	4870	490	cold flow
	40	280	2105	3650	-	5370	520	
	60	280	1995	3625	-	4335	460	cold flow
	80	280	2615	3605		4595	460	cold flow
A2b-11	40	240	1610	2695	-	4325	530	
	60	240	1430	2775	-	3930	510	
	80	240	1390	2835	-	4835	540	
	40	260	2035	3225	-	4600	510	cold flow
	60	260	2190	3335	-	5360	520	cold flow
	80	260	2560	3440	-	5510	530	cold flow
	40	280	1765	3070	-	4740	490	
	60	280	2050	3625	-	4670	480	
	80	280	1955	3655	-	4930	490	
A2b-12	40	240	1780	2735	-	3635	470	
	60	240	1485	2675	-	3400	490	
	80	240	2085	3090	-	4560	500	cold flow
	40	260	2600	3165	-	4225	490	cold flow
	60	260	2110	3615	-	4515	470	cold flow
	80	260	2410	3455	-	4470	450	cold flow
	40	280	1755	3475	-	5060	500	
	60	280	1885	3400	-	4570	490	
	80	280	2290	3775	-	5265	480	
A2b-13	40	240	2470	3140	-	3690	430	cold flow
	60	240	-	-	-	2550	0	frozen
	80	240	-	-	-	2500	0	frozen
	40	260	-	-	-	2500	60	frozen
	60	260	-	-	-	2300	80	frozen
	80	260	-	-	-	2745	80	frozen
	40	280	2395	3530	-	4950	490	cold flow
	60	280	2150	3525	-	4745	490	cold flow
	80	280	2425	4040	-	5255	500	cold flow
A2b-14	40	240	-	-	-	2605	100	frozen
	60	240	-	-	-	2400	0	frozen
	80	240	-	-	-	2555	0	frozen
	40	260	2255	3015	-	4650	530	cold flow
	60	260	2500	3375	-	4270	480	cold flow
	80	260	2245	3400	-	4615	470	cold flow
	40	280	2170	3645	-	4450	480	
	60	280	2085	3790	-	4855	480	
	80	280	2210	3680	-	4885	470	cold flow

TABLE 34

PHYSICAL PROPERTIES OF COMPOUNDS A2b-6, A2b-7, A2b-8, A2b-9, AND A2b-10 TESTED AT -75°C

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Remarks
A2b-6	40	240	1830	3025	-	3755	470	
	60	240	1885	3160	-	4295	500	
	80	240	2225	3680	-	4945	500	cold flow
	40	260	2075	3385	-	4805	510	
	60	260	2385	3705	-	4870	490	
	40	280	-	-	-	3490	0	frozen
	60	280	-	-	-	3295	0	frozen
	Other cures not tested - showed cold flow or froze at -70°C							
A2b-7	40	240	2425	3245	-	4410	500	cold flow
	60	240	-	-	-	3415	0	frozen
	80	240	-	-	-	2710	0	frozen
	40	260	-	-	-	2830	0	frozen
	Other cures not tested - showed cold flow or froze at -70°C							
A2b-8	40	240	-	-	-	3075	0	frozen
	Other cures not tested - showed cold flow or froze at -70°C							
A2b-9	Not tested - all cures showed cold flow or froze at -70°C							
A2b-10	Not tested - all cures showed cold flow or froze at -70°C							

FACTUAL DATA (CONTINUED)

TASK A PHASE 2 PART B (CONTINUED)

TABLE 35

PHYSICAL PROPERTIES OF COMPOUNDS A2b-6, A2b-11, A2b-12, A2b-13, AND A2b-14 TESTED AT -75°C

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Remarks
A2b-6	40	240	1830	3025	-	3755	470	
	60	240	1885	3160	-	4295	500	
	80	240	2225	3680	-	4945	500	cold flow
	40	260	2075	3385	-	4805	510	
	60	260	2385	3705	-	4870	490	
	40	280	-	-	-	3490	0	frozen
	60	280	-	-	-	3295	0	frozen
	Other cures not tested - showed cold flow or froze at -70°C							
A2b-11	40	240	-	-	-	2555	0	frozen
	60	240	-	-	-	2710	20	frozen
	80	240	2215	3725	-	4575	470	cold flow
	40	280	2320	3690	-	4770	470	cold flow
	60	280	-	-	-	3020	0	frozen
	80	280	-	-	-	3160	0	frozen
	Other cures not tested - showed cold flow or froze at -70°C							
A2b-12	60	240	2375	3560	-	4320	480	cold flow
	40	280	-	-	-	3000	0	frozen
	60	280	-	-	-	2290	0	frozen
	Other cures not tested - showed cold flow or froze at -70°C							
A2b-13	Not tested - all cures showed cold flow or froze at -70°C							
A2b-14	40	280	-	-	-	3805	0	frozen
	60	280	-	-	-	3750	0	frozen
	Other cures not tested - showed cold flow or froze at -70°C							

FACTUAL DATA (continued)

TASK A, Phase 2, Part B (continued)

According to the supplier, Mobilsol 'L', a product of the Socony Mobiloil Company, Inc., is an excellent low-temperature plasticizer for neoprene. Three compounds were prepared to determine the properties of this product. Their formulations are given in Table 36.

The purpose of these compounds was to compare Mobilsol 'L' with Butyl Oleate and Dibutyl Sebacate. Plates were dipped from these compounds according to standard procedure and cured for 60, 90, and 120 minutes at 240°F, 260°F, and 280°F.

Physical properties were determined at room temperature and at -50°C, and the results of these tests are recorded in Tables 37 and 38.

It can be seen from the results in Table 37 that there is relatively little difference in the room-temperature physical properties when Mobilsol 'L' is substituted for Dibutyl Sebacate or Butyl Oleate.

Mobilsol 'L' tends to show slightly higher modulus and decidedly higher tensile strength, but the elongation at break is almost the same. Mobilsol 'L' has slightly higher tear strength.

A study of Table 38, moreover, shows immediately and clearly that Mobilsol 'L' is much inferior to both Butyl Oleate and Dibutyl Sebacate at low temperatures. Only two samples, those cured for 60 and 90 minutes at 240°F, showed any elongation whatsoever, and the 200% modulus of the sample cured for 90 minutes is extremely high indicating a severe cold flow condition.

It may, therefore, be concluded that Mobilsol 'L' is unsatisfactory as a plasticizer for neoprene balloon compounds, and no further work will be done with this material.

A sample of Butoxy Ethyl Oleate, which is chemically identical to Paraflux C-325, was received from Kessler Chemical Company. It was decided to evaluate this material in direct comparison with Paraflux C-325, and two compounds were prepared. These were identified as A2b-17 and A2b-18, the formulations of which are given in Table 39.

Plates were dipped from these compounds according to standard procedure and cured for 60, 90, and 120 minutes at 240°F, 260°F, and 280°F. Physical properties were determined, and the results are given in Table 40.

TABLE 36

FORMULATIONS DESIGNED TO DETERMINE PROPERTIES OF MOBILSOL 'L'

Formulation No.	A3a-1	A2b-15	A2b-16
Neoprene 750	80.0	80.0	80.0
Neoprene 571	20.0	20.0	20.0
Zinc Oxide	5.0	5.0	5.0
Neozone 'D'	2.0	2.0	2.0
N.B.C.	3.0	3.0	3.0
Accelerator 833	1.0	1.0	1.0
Sunaptic Acid	1.0	1.0	1.0
Aquarex SMO	0.5	0.5	0.5
Dibutyl Sebacate	6.25	-	-
Butyl Oleate	-	6.25	-
Mobilsol 'L'	-	-	6.25

FACTUAL DATA (continued)

TABLE 37

PHYSICAL PROPERTIES OF COMPOUNDS A3a-1, A2b-15, AND A2b-16
TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F.)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
A3a-1	60	240	90	155	315	1310	965	58
	90	240	120	175	310	1630	945	61
	120	240	125	180	320	1600	900	64
	60	260	130	175	315	1400	920	60
	90	260	135	180	300	1705	920	60
	120	260	135	190	305	1725	925	70
	60	280	120	175	290	1945	925	62
	90	280	125	165	255	1975	920	65
	120	280	135	170	285	2000	910	66
A2b-15	60	240	100	130	240	1260	1080	52
	90	240	100	135	240	1480	1080	58
	120	240	105	140	235	1450	1070	65
	60	260	105	145	220	1605	1075	57
	90	260	120	150	220	1610	1070	60
	120	260	130	160	225	1690	1055	71
	60	280	135	170	265	1910	950	71
	90	280	130	170	220	2000	1080	73
	120	280	140	175	270	2270	950	76
A2b-16	60	240	120	170	265	1520	1075	67
	90	240	125	170	275	1740	1080	69
	120	240	135	175	275	1790	1075	76
	60	260	145	175	270	2180	1080	86
	90	260	150	175	290	2300	1040	88
	120	260	155	185	280	2280	1045	74
	60	280	150	190	315	2550	975	82
	90	280	150	190	350	2615	930	88
	120	280	155	195	375	2635	920	86

FACTUAL DATA (continued)

TASK A, Phase 2, Part B (continued)

TABLE 38

PHYSICAL PROPERTIES OF COMPOUNDS A3a-1, A2b-15, AND A2b-16 TESTED AT -50°C

Compound No.	Cure Time (mins)	Cure Temp, (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A3a-1	60	240	850	1515	3875	4395	630
	90	240	145	1425	4020	4210	610
	120	240	985	1860	4210	5205	625
	60	260	1420	2260	5965	5965	600
	90	260	1675	2445	-	4895	570
	120	260	1880	2885	-	5125	570
	60	280	1950	3420	-	5995	540
	90	280	2170	3585	-	5825	520
	120	280	2540	3620	-	5765	510
A2b-15	60	240	375	1045	2470	4945	680
	90	240	430	860	3710	4325	650
	120	240	285	615	2625	4635	640
	60	260	710	1425	3160	3360	620
	90	260	765	1430	3395	4670	660
	120	260	1615	2645	-	5735	590*
	60	280	1465	2445	6035	6035	600*
	90	280	1325	2900	5960	5960	600*
	120	280	1525	2400	5455	5455	600*
A2b-16	60	240	1855	2960	-	3830	570*
	90	240	3150	3535	-	5785	530**
	120	240	-	-	-	-	- ***
	Samples cured for 60, 90, and 120 minutes at 260°F were frozen						
	Samples cured for 60, 90, and 120 minutes at 280°F were frozen						

* Slight cold flow
** Cold flow
*** Frozen

TABLE 39

FORMULATIONS DESIGNED TO DETERMINE PROPERTIES OF BUTOXY ETHYL OLEATE

Formulation No.	A2b-17	A2b-18
Neoprene 750	100.0	100.0
Zinc Oxide	5.0	5.0
Neozone 'D'	2.0	2.0
N.B.C.	3.0	3.0
Accelerator 833	1.0	1.0
Sunaptic Acid	1.0	1.0
Aquarex SMO	0.5	0.5
Paraflux C-325	12.0	-
Butoxy Ethyl Oleate	-	12.0

FACTUAL DATA (continued)

TASK A, Phase 2, Part B (continued)

TABLE 40

PHYSICAL PROPERTIES OF COMPOUNDS A2b-17 AND A2b-18
TESTED AT ROOM TEMPERATURE AND AT -50°C

Compound No.	Test Temp. (°C)	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elong. at Brk. (%)	Tear Strength (lbs/in)
A2b-17	+20	60	240	55	75	135	660	1245	33
	+20	90	240	65	85	140	830	1260	37
	+20	120	240	75	90	145	1175	1290	42
	+20	60	260	70	80	100	1100	1270	44
	+20	90	260	70	85	120	1200	1265	45
	+20	120	260	80	95	125	1370	1210	48
	+20	60	280	70	100	150	1210	1105	50
	+20	90	280	75	140	190	1685	1050	50
	+20	120	280	95	140	195	1550	1005	50
A2b-18	+20	60	240	50	75	165	800	1275	38
	+20	90	240	70	100	165	1150	1275	46
	+20	120	240	85	110	150	1560	1275	50
	+20	60	260	70	95	145	1100	1270	37
	+20	90	260	85	110	155	1250	1175	51
	+20	120	260	105	145	190	1600	1065	55
	+20	60	280	105	130	170	1480	1035	42
	+20	90	280	100	135	165	1555	1040	49
	+20	120	280	110	135	190	1770	1110	50
A2b-17	-50	60	280	355	410	2550	3215	620	-
	-50	90	280	395	765	3240	4180	650	-
	-50	120	280	360	720	3000	3505	620	-
A2b-18	-50	60	280	470	1355	4530	4530	600	-
	-50	90	280	310	740	2785	3865	640	-
	-50	120	280	330	990	3645	4725	630	-

FACTUAL DATA (continued)

TASK A, Phase 2, Part B (continued)

In view of the similarity of the results obtained at room temperature, the testing at -50°C was restricted to the 60-, 90-, and 120-minute cures at 280°F.

A study of these results indicates that at room temperature, Butoxy Ethyl Oleate is somewhat faster curing than Paraflux C-325 but that, in general, the physical properties obtainable are almost identical. At -50°C, the physical properties, particularly the ultimate elongation, are virtually the same.

Therefore, a sufficient quantity of dual-purpose compound using Butoxy Ethyl Oleate was prepared, and balloons were manufactured and flown. The physical properties of this compound and the flight results of the balloons are recorded in Task A, Phase 3 and Phase 4.

Samples of two additional plasticizers were obtained, both of them claimed by the manufacturers to confer excellent low-temperature properties on neoprene compounds.

The first of these plasticizers bears the tradename, Ohopex R-9, and was supplied by Stoney-Mueller. The second is made by Harwick Standard Chemical Company and is sold under the name of Plasticizer SC. In neither case is the nature of the material disclosed.

Two compounds were prepared containing Ohopex R-9, and two containing Plasticizer SC, the formulations for which are given in Table 41.

Plates were dipped according to standard procedure. However, when plates were dipped from compound A2b-20, it proved impossible to obtain a coherent film. It would appear that this plasticizer solvates the neoprene polymer to such a degree that the gel has insufficient strength to cohere, bending to break away from the dipping form as soon as it is deposited.

No further work was done with this compound, but physical properties at room temperature and at -40°C were determined on compound A2b-19 and A2b-21. Physical properties were determined at room temperature and -70°C on compound A2b-22. The results of these tests are given in Table 42.

A study of these results shows that Ohopex R-9 has properties very similar to Dibutyl Sebacate at both room temperature and at -40°C when tested in a day-flight compound.

FACTUAL DATA (continued)

TASK A, Phase 2, Part B (continued)

TABLE 41

FORMULATIONS OF COMPOUNDS CONTAINING
OHOPEX R-9 OR PLASTICIZER SC

Formulation No.	A2b-19	A2b-20	A2b-21	A2b-22
Neoprene 750	80.0	80.0	80.0	80.0
Neoprene 571	20.0	20.0	20.0	20.0
Zinc Oxide	5.0	5.0	5.0	5.0
Neozone 'D'	2.0	2.0	2.0	2.0
N.B.C.	3.0	3.0	3.0	3.0
Accelerator 833	1.0	1.0	1.0	1.0
Sunaptic Acid	1.0	1.0	1.0	1.0
Aquarex SMO	0.5	0.5	0.5	0.5
Ohopex R-9	6.25	25.0	-	-
Plasticizer SC	-	-	6.25	25.0
Sulphur	-	3.0	-	3.0

FACTUAL DATA (continued)

TASK A, Phase 2, Part B (continued)

TABLE 42

PHYSICAL PROPERTIES OF COMPOUNDS A2b-19, A2b-21 AND A2b-22 TESTED AT ROOM-TEMPERATURE, -40°C, AND -70°C.

Compound No.	Test Temp. (°C.)	Cure Time (mins)	Cure Temp. (°F.)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A2b-19	+20	60	280	125	185	275	2210	940
	+20	90	280	140	190	280	2140	940
	+20	120	280	155	210	305	2320	920
	-40	60	280	230	780	2875	3720	650
	-40	90	280	255	820	3320	4125	680
	-40	120	280	250	845	3385	4330	670
A2b-21	+20	60	280	125	165	225	750	760
	+20	90	280	115	150	250	1980	890
	+20	120	280	120	180	320	2190	860
	-40	60	280	--	--	--	--	frozen
	-40	90	280	--	--	--	--	frozen
	-40	120	280	--	--	--	--	frozen
A2b-22	+20	60	280	85	105	145	705	890
	+20	90	280	80	110	145	1390	980
	+20	120	280	80	110	165	1000	900
	-70	60	280	--	--	--	--	frozen
	-70	90	280	--	--	--	--	frozen
	-70	120	280	--	--	--	--	frozen

FACTUAL DATA (continued)

TASK A, Phase 2, Part B (continued)

Since it shows no advantages over Dibutyl Sebacate and because of its unsatisfactory behavior when the amount of plasticizer is raised to 25 parts, no further work is planned with this material.

Plasticizer SC is unsuitable in every way. Its low-temperature characteristics are extremely poor, both compounds freezing at the customary test temperature for the type of compound under investigation. No further work is planned for this material.

Part C: Antioxidants and Antiozonants

Investigations completed in a previous contract indicated that, although present balloon compounds have very good oxygen and ozone resistance, it is possible to effect further improvements.

Since it is necessary to perform flights to determine whether such improvement results in better performance, sufficient quantities of the two most promising antiozonants were ordered. Efforts to prepare dispersions of these materials proved unsuccessful, and the suppliers were not able to solve our problems.

Two other materials of a similar chemical composition were, therefore, obtained. These were Agerite DPPD from R. T. Vanderbilt Company and Akroflex CD from E.I. du Pont de Nemours. Agerite DPPD is stated by the manufacturer to be diphenyl-p-phenylene diamine. Akroflex CD is a mixture of diphenyl-p-phenylene diamine and N-phenyl-beta-naphthylamine.

No problems were encountered in dispersing either of these materials, and three compounds were prepared. The formulations are given in Table 43.

Plates were dipped according to standard procedure and cured for 120 minutes at 240° F., 260°F., and 280° F. Physical properties were determined at room temperature, and the ozone resistance was determined by exposing dumbell samples, stretched 200%, to an ozone concentration of 80 parts per million and determining the time to rupture. These results are given in Table 44.

FACTUAL DATA (continued)

TASK A, Phase 2, Part C (continued)

TABLE 43

FORMULATIONS OF COMPOUNDS WITH VARIOUS ANTIOZONANTS

Formulation No.	A2c-1	A2c-2	A2c-3
Neoprene 750	80.00	80.00	80.00
Neoprene 571	20.00	20.00	20.00
Zinc Oxide	5.00	5.00	5.00
Neozone 'D'	2.00	2.00	2.00
Accelerator 833	1.00	1.00	1.00
Sunaptic Acid	1.00	1.00	1.00
Aquarex SMO	0.50	0.50	0.50
Dibutyl Sebacate	6.25	6.25	6.25
N.B.C.	3.00	-	-
Agerite DPPD	-	3.00	-
Akroflex CD	-	-	3.00

FACTUAL DATA (continued)

TASK A. Phase 2. Part C (continued)

TABLE 44

PHYSICAL PROPERTIES AND OZONE RESISTANCE OF COMPOUNDS A2c-1, A2c-2, AND A2c-3 TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)	Time to Rupture in Ozone (mins)
A2c-1	120	240	140	175	325	1920	935	68	60
	120	260	140	180	340	2050	930	73	110
	120	280	145	175	355	2070	910	92	120
A2c-2	120	240	140	195	420	1650	900	69	350
	120	260	145	185	400	1805	870	76	320
	120	280	165	215	550	2225	820	96	240*
A2c-3	120	240	125	175	330	1535	910	58	55
	120	260	130	165	285	1635	915	64	80
	120	280	125	175	280	1920	915	67	100

* Sample had not ruptured at conclusion of test.

FACTUAL DATA (continued)

TASK A, Phase 2, Part C (continued)

The standardization of the ozone chamber, and the method of conducting the tests are described in Task B, Phase 2.

A study of the results in Table 44 shows that Agerite DPPD is a much more effective antiozonant than N.B.C. or Akroflex CD, the latter being approximately equal to N.B.C. Agerite DPPD also results in a compound with higher modulus and lower elongation than does N.B.C. or Akroflex CD. If the same tensile strength as is obtained using N.B.C. is aimed for, then means of increasing the elongation of the Agerite DPPD compound must be sought.

A similar series of tests using small balloons was also conducted in the ozone chamber, and the superiority of Agerite DPPD as an antiozonant was confirmed, the life of the A2c-2 balloons being approximately six times that of the balloons made from compounds A2c-1 and A2c-3.

* * * * * * *

During a previous investigation of antioxidants, it was observed that Wingstay 'T', while being only a moderate antioxidant, produced a compound with an unusually high elongation. It was considered worthwhile to examine this property of Wingstay 'T' further, and two compounds were prepared. The formulations are given in Table 45.

Plates were dipped from these compounds according to standard procedure and cured for 60, 90, and 120 minutes at 240°F, 260°F., and 280°F. Physical properties were determined at room-temperature, -40°C., and -50°C. The results of these tests are given in Tables 46 through 48.

TABLE 45

FORMULATIONS OF COMPOUNDS CONTAINING WINGSTAY 'T'

Formulation No.	A2c-10	A2c-11
Neoprene 750	100.0	100.0
Zinc Oxide	1.0	5.0
Wingstay 'T'	2.0	2.0
N.B.C.	3.0	3.0
Accelerator 833	1.0	1.0
Sunaptic Acid	1.0	1.0
Aquarex SMO	0.5	0.5
Butyl Oleate	10.0	10.0

TABLE 46

PHYSICAL PROPERTIES OF COMPOUNDS A2c-10 AND A2c-11
TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
A2c-10	60	240	85	100	180	1195	1200	50
	90	240	90	110	195	1110	1180	56
	120	240	95	115	185	1135	1165	55
	60	260	95	120	200	1240	1135	57
	90	260	80	105	150	1500	1230	51
	120	260	105	125	160	1350	1165	54
	60	280	100	120	165	1375	1225	60
	90	280	135	145	195	2000	1100	79
	120	280	125	150	190	1805	1060	89
A2c-11	60	240	100	130	205	1245	1225	53
	90	240	90	120	200	1270	1240	53
	120	240	85	120	200	1225	1175	51
	60	260	90	125	195	1170	1175	47
	90	260	100	120	175	1330	1190	52
	120	260	110	135	175	1515	1150	56
	60	280	125	155	190	1350	1110	56
	90	280	130	160	215	1830	990	81
	120	280	120	155	190	1760	1070	78

TABLE 47

PHYSICAL PROPERTIES OF COMPOUNDS A2c-10 AND A2c-11 TESTED AT -40°C

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A2c-10	60	240	115	175	925	2895	780
	90	240	115	170	950	3390	780
	120	240	120	180	940	3630	780
	60	260	130	205	940	3370	780
	90	260	140	240	1030	2665	750
	120	260	120	185	940	3965	800
	60	280	130	175	890	3585	800
	90	280	130	190	1060	3845	780
	120	280	130	175	1015	3155	740
A2c-11	60	240	160	335	1170	3110	780
	90	240	130	240	965	2695	760
	120	240	135	245	925	3150	790
	60	260	120	215	850	2775	780
	90	260	105	195	880	3270	800
	120	260	130	185	970	3965	820
	60	280	110	205	830	3210	790
	90	280	140	215	1525	3525	720
	120	280	135	190	1215	3780	760

TABLE 48

PHYSICAL PROPERTIES OF COMPOUNDS A2c-10 AND A2c-11
TESTED AT -50°C

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A2c-10	60	240	325	960	-	2645	570
	90	240	420	890	-	2475	570
	120	240	500	1160	-	3265	570
	60	260	650	1320	3910	3910	600
	90	260	765	1475	4235	4235	600
	120	260	745	1510	4085	5030	640
	60	280	775	1500	-	3875	580
	90	280	985	1860	5000	5560	630
	120	280	750	1690	4625	5300	620
A2c-11	60	240	460	1040	-	2945	570
	90	240	510	1120	-	3465	560
	120	240	520	1105	3655	3980	620
	60	260	530	1230	3795	4290	620
	90	260	585	1285	4090	4580	630
	120	260	570	1250	3955	5200	660
	60	280	520	1280	3815	4705	650
	90	280	825	1920	5065	5895	650
	120	280	850	1805	4560	5540	640

TASK A, Phase 2, Part C (continued)

A study of these results shows that, although the previous figures were not confirmed, the incorporation of Wingstay 'T' results in a significant increase in elongation at room-temperature and at low temperatures. Since Neoprene 400 has a low elongation, it was felt that the addition of Wingstay 'T' might be beneficial in Neoprene 400 compounds.

Accordingly, two compounds were prepared, one of which contained Wingstay 'T' and N.B.C. and the other Wingstay 'T' only. Both compounds were based on Neoprene 400, and the formulations are given in Table 49.

Plates were dipped according to standard procedure and cured for 60, 90, and 120 minutes at 240°F., 260°F., and 280°F. Physical properties were determined at room temperature, -40°C., and -50°C.

Because Neoprene 400 is reported to have much better ozone resistance than other neoprene polymers, it was decided to determine the ozone resistance of these compounds also. The results of these tests are given in Tables 50, 51 and 52.

A study of these results shows that at all temperatures tested, A2c-14 (the compound that does not contain N.B.C.) has higher elongation than A2c-13. Both compounds show very good tear strength, particularly at the higher cures. The room-temperature modulus is very high, and A2c-14 shows higher tensile strength at room temperature at all cures except 120 minutes at 280°F.

The compound without N.B.C. (A2c-14) shows much poorer ozone resistance than the one containing N.B.C. (A2c-13). It does, however, have a resistance to ozone comparable to a standard balloon compound based on Neoprene 750.

These results indicate that Wingstay 'T' does improve the elongation of Neoprene 400 although elimination of N.B.C. seems to have a more marked effect. The modulus of these compounds is excessively high, however, and the elongation is too low for good balloon performance. Combinations of Neoprene 750 and Neoprene 400 gave compounds with good tensile strength and modulus, but the elongation was lower than was desirable. It would seem, therefore, that the addition of Wingstay 'T' to such compounds would result in the elongation desired.

Two compounds, the formulations of which are given in Table 53 were prepared to check the effect of adding Wingstay 'T' to compounds containing combinations of Neoprene 750 and Neoprene 400.

TABLE 49

FORMULATIONS OF COMPOUNDS CONTAINING NEOPRENE 400 AND WINGSTAY 'T'

Formulation No.	A2c-13	A2c-14
Neoprene 400	100.0	100.0
Zinc Oxide	1.0	1.0
Wingstay 'T'	2.0	2.0
N.B.C.	3.0	-
Accelerator 833	1.0	1.0
Sunaptic Acid	1.0	1.0
Aquarex SMO	0.5	0.5
Butyl Oleate	10.0	10.0

TABLE 50

PHYSICAL PROPERTIES OF COMPOUNDS A2c-13 AND A2c-14
TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)	Time to Rupture in Ozone (mins)
A2c-13	60	240	350	890	1710	1960	700	142	
	90	240	340	890	1650	2025	695	148	
	120	240	345	890	1645	1880	655	145	
	60	260	375	905	1735	2295	725	181	
	90	260	350	815	1650	2280	750	177	140
	120	260	345	845	1675	2690	785	181	
	60	280	420	865	1740	2805	735	218	
	90	280	400	900	1790	2660	755	228	
	120	280	385	965	1865	3055	780	245	
A2c-14	60	240	380	945	1785	2715	770	175	
	90	240	385	1090	1865	2915	785	186	
	120	240	385	1010	1910	2985	800	218	
	60	260	390	830	1690	3180	865	193	
	90	260	375	970	1690	3065	855	208	45
	120	260	360	800	1545	2865	855	211	
	60	280	535	1120	1850	3125	810	225	
	90	280	500	1085	1855	3670	875	233	
	120	280	465	890	1570	3010	875	208	
Standard Balloon Compound									50

TABLE 51

PHYSICAL PROPERTIES OF COMPOUNDS A2c-13 AND A2c-14 TESTED AT -40°C

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A2c-13	60	240	1980	3545	-	3840	430
	90	240	2135	4315	-	4860	450
	120	240	1845	3880	-	4215	440
	60	260	2210	4320	-	4750	440
	90	260	2085	3910	-	4700	450
	120	260	2395	4550	-	5385	470
	60	280	2290	4520	-	5250	470
	90	280	4045	4200	-	5600	530
	120	280	2225	4430	-	5530	490
A2c-14	60	240	2475	4430	-	5515	490
	90	240	2385	4390	-	5985	540
	120	240	2580	4560	-	6725	570
	60	260	2475	4550	-	5525	540
	90	260	2525	4750	-	6290	530
	120	260	2230	4010	-	5245	530
	60	280	2265	4115	-	5630	550
	90	280	2125	3835	-	4855	490
	120	280	2330	4215	-	5210	500

TABLE 52

PHYSICAL PROPERTIES OF COMPOUNDS A2c-13 AND A2c-14
TESTED AT -50°C

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A2c-13	60	240	2810	-	-	4280	340
	90	240	3265	-	-	4535	360
	120	240	2925	-	-	4165	370
	60	260	3380	5005	-	5795	430
	90	260	3150	4880	-	5770	450
	120	260	3600	5225	-	5800	530
	60	280	3630	5290	-	5770	430
	90	280	3660	-	-	4865	380
	120	280	3300	-	-	4780	370
A2c-14	60	240	3700	5250	-	6010	470
	90	240	3815	5615	-	6205	450
	120	240	3450	5440	-	6345	470
	60	260	3610	5500	-	6305	470
	90	260	3630	5645	-	6805	500
	120	260	3455	5210	-	5805	470
	60	280	3205	4891	-	5555	450
	90	280	3075	4950	-	5900	450
	120	280	3170	4945	-	5395	430

TABLE 53

FORMULATIONS OF COMPOUNDS CONTAINING NEOPRENE 750, NEOPRENE 400, AND WINGSTAY 'T'

Formulation No.	A2c-15	A2c-16
Neoprene 750	60.0	70.0
Neoprene 400	40.0	30.0
Zinc Oxide	5.0	5.0
Wingstay 'T'	2.0	2.0
N.B.C.	3.0	3.0
Accelerator 833	1.0	1.0
Sunaptic Acid	1.0	1.0
Aquarex SMO	0.5	0.5
Butyl Oleate	10.0	10.0

FACTUAL DATA (continued)

TASK A. Phase 2. Part C (continued)

Plates were dipped according to standard procedure and cured for 60, 90 and 120 minutes at 240°F., 260°F., and 280°F. Physical properties were determined at room temperature. It has been shown that Wingstay 'T' has no adverse effect on low-temperature properties, and for this reason low-temperature testing was omitted. The physical properties at room temperature are given in Table 54.

A study of these results shows that the anticipated results have been obtained. The physical properties of either of these compounds suggest that balloons made from them should perform extremely well.

During the course of a previous contract (DA-36-039-SC-38239), it was established that Lytron 615, a polystrene latex, was effective in raising modulus and maintaining elongation, both at room temperature and at low temperatures. However, balloons made from such compounds performed in a very erratic fashion although some excellent flights were obtained. Initial tests indicated that the compounds containing Lytron 615 had poor ozone resistance.

The effect of adding Agerite DPPD to such compounds was therefore investigated. Altogether, four compounds were compared. These were identified as A3-105, A3-105 with Agerite DPPD, A3-112, and A3-112 with N.B.C. Plates were dipped according to standard procedure and cured for 120 minutes at 240°F., 260°F., and 280°F. Samples were exposed to an ozone concentration of 80 parts per million, and the results are recorded in Table 55.

These results show the ozone resistance of A3-112 is superior to that of A3-112 with N.B.C. and equal to that of A3-105. A3-105 with Agerite DPPD is much superior to A3-105 which further confirms the excellent protection afforded by Agerite DPPD.

A sample of the antiozonant bearing the tradename B.T.N. was received. This material is supplied by Henley and Company and is claimed to be identical in chemical composition to du Pont's N.B.C.

Since it has been established that N.B.C. confers specific desirable properties on meteorological balloon films, it was considered advisable to evaluate a possible alternate source for this critical material.

TABLE 54

PHYSICAL PROPERTIES OF COMPOUNDS A2c-15 AND A2c-16
TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (^{o}F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
A2c-15	60	240	150	230	525	1360	925	67
	90	240	150	235	520	1390	935	73
	120	240	150	225	485	1600	965	75
	60	260	155	235	525	1635	945	78
	90	260	175	250	560	2000	960	85
	120	260	180	285	655	2125	935	100
	60	280	145	210	430	1830	1065	69
	90	280	140	200	385	2160	1000	70
	120	280	140	200	425	2410	980	87
A2c-16	60	240	120	190	350	1400	1030	54
	90	240	115	170	305	1515	1075	60
	120	240	110	165	295	1805	1120	64
	60	260	75	110	175	1265	1155	46
	90	260	90	120	175	1340	1160	50
	120	260	105	130	190	1560	1135	53
	60	280	135	185	355	1920	1020	76
	90	280	140	200	385	2160	1000	70
	120	280	140	200	425	2410	980	87

TABLE 55

EFFECT OF AGERITE DPPD ON OZONE RESISTANCE OF COMPOUNDS CONTAINING LYTRON 615

Compound No.	Cure Time (mins)	Cure Temp. (^{o}F)	Time to Rupture (mins)
A3-112 with N.B.C.	120	240	20
A3-112	120	240	55
A3-105	120	240	40
A3-105 with DPPD	120	240	480+
A3-112 with N.B.C.	120	260	20
A3-112	120	260	145
A3-105	120	260	150
A3-105 with DPPD	120	260	480+
A3-112 with N.B.C.	120	280	20
A3-112	120	280	110
A3-105	120	280	120
A3-105 with DPPD	120	280	480+

FACTUAL DATA (continued)

TASK A, Phase 2, Part C (continued)

A compound identified as A2c-17 was prepared. This compound contained B.T.N. in place of N.B.C. but was otherwise identical to compound A3-105. The formulations for these two compounds are given in Table 56.

Plates were dipped from these compounds in accordance with standard procedure and cured for 60, 90, and 120 minutes at 280°F. In view of the presumable chemical identity of the two materials, the cure was restricted to one temperature in order to reduce laboratory testing. Physical properties of the films were determined at room temperature and at -50°C., and the results of these tests are recorded in Table 57.

A study of this table shows that B.T.N. tends to accelerate the cure. Its antiozonant characteristics are equal to those of N.B.C.; therefore, this material may be considered to show some practical advantages in that cure times could be reduced with attendant gains in processing. The final characteristics of the cured film, providing the cure time is adjusted to produce the same state of cure, are identical to those obtained using N.B.C.

In order to prove the flight performance of this material, balloons were made from compound A2c-17 which was assigned the number A3-128. The results of these flights are reported in Task A, Phase 4.

TABLE 56

FORMULATIONS DESIGNED TO DETERMINE PROPERTIES OF B.T.N.

Formulation No.	A3-105	A2c-17
Neoprene 750	80.0	80.0
Neoprene 571	20.0	20.0
Zinc Oxide	5.0	5.0
Neozone 'D'	2.0	2.0
N.B.C.	3.0	-
B.T.N.	-	3.0
Accelerator 833	1.0	1.0
Sunaptic Acid	1.0	1.0
Aquarex SMO	0.5	0.5
Dibutyl Sebacate	6.25	6.25

FACTUAL DATA (continued)

TASK A, Phase 2, Part C (continued)

TABLE 57

PHYSICAL PROPERTIES OF COMPOUNDS A3-105 AND A2c-17 TESTED AT ROOM-TEMPERATURE AND AT -50°C.

Compound No.	Test Temp. (°C.)	Cure Time (mins)	Cure Temp. (°F.)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elong. at Brk. (%)	Tear Strength (lbs/in)
A3-105	+20	60	280	140	200	320	2440	960	84
	+20	90	280	145	195	330	2387	930	80
	+20	120	280	150	215	380	1980	880	86
A2c-17	+20	60	280	150	210	345	2165	935	84
	+20	90	280	140	200	325	2125	940	78
	+20	120	280	140	195	310	1815	905	72
A3-105	-50	60	280	1950	3420	-	5995	540	-
	-50	90	280	2170	3585	-	5825	520	-
	-50	120	280	2540	3620	-	5765	510	-
A2c-17	-50	60	280	2175	3335	-	6205	580	-
	-50	90	280	2015	3335	-	6020	550	-
	-50	120	280	1745	3210	-	5145	520	-

FACTUAL DATA (continued)

TASK A, Phase 2 (continued)

Part D: Accelerators

Previous investigations conducted during the course of Contract No. DA-36-039-SC-72386 had indicated that Merac, an accelerator produced by Pennsalt Chemical Corporation, was somewhat superior to Accelerator 833 in that it provided higher modulus without reducing elongation. This should result in balloons with faster rates of ascent.

Accordingly, four compounds were designed, two of which were standard day-flight types and two of which were fast-rising types. These formulations are given in Table 58.

Plates were dipped from these compounds according to standard procedure and cured for 60, 90, and 120 minutes at 240°F., 260°F., and 280°F. Physical properties were determined at room temperature, and the results of these tests are recorded in Table 59.

A study of these results shows that in the case of the pair of compounds, A2a-4 and A2d-1, the use of Merac makes little difference to the physical properties; there is a slight loss in elongation at all cures, and no appreciable gain in modulus. In the case of compounds A3-102 and A2d-2, there is very little difference in any of the physical characteristics.

Since Merac is a water-soluble accelerator and offers certain promising advantages, it was considered worthwhile to pursue this investigation further.

Therefore, four more compounds were designed, one pair of which contained Neoprene 400 and had a sufficiently high plasticizer content for dual-purpose balloons. The other pair consisted of standard balloon compounds. In each pair, one compound contained Accelerator 833 and the other contained Merac. The formulations of these compounds are given in Table 60.

Plates were dipped according to standard procedure and cured for 60, 90 and 120 minutes at 240°F., 260°F., and 280°F. The physical properties were determined at room temperature, at -70°C. in the case of A3-119 and A2d-3, and at -50°C. in the case of A3-105 and A2d-4. The temperature of -50°C. was used of necessity and not by choice because the cold box temperature regulator would not maintain temperature accurately at above -50°C. The results of these tests are given in Tables 61 and 62.

TABLE 58

FORMULATIONS DESIGNED TO DETERMINE THE EFFECT OF REPLACING ACCELERATOR 833 WITH MERAC

Formulation No.	A2a-4	A2d-1	A3-102	A2d-2
Neoprene 750	100.0	100.0	100.0	100.0
Zinc Oxide	5.0	5.0	5.0	5.0
Neozone 'D'	2.0	2.0	2.0	2.0
N.B.C.	3.0	3.0	3.0	3.0
Accelerator 833	1.0	-	1.0	-
Merac	-	1.0	-	1.0
Sunaptic Acid	1.0	1.0	1.0	1.0
Aquarex SMO	0.5	0.5	0.5	0.5
Butyl Oleate	10.0	10.0	5.0	5.0
Sulphur	-	-	3.0	3.0

TABLE 59

PHYSICAL PROPERTIES OF COMPOUNDS A2a-4, A2d-1, A3-102, AND A2d-2
TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
A2a-4	60	240	55	100	190	980	1150	37
	90	240	65	110	200	1085	1140	37
	120	240	90	120	210	1150	1135	43
	60	260	100	120	170	1430	1110	48
	90	260	100	125	175	1445	1110	55
	120	260	90	120	170	1430	1130	48
	60	280	110	135	175	1500	1095	55
	90	280	115	150	195	1700	1045	56
	120	280	125	170	220	1900	980	63
A2d-1	60	240	85	135	265	1160	1025	43
	90	240	95	130	250	1220	1030	42
	120	240	95	135	255	1150	1035	46
	60	260	100	130	190	1325	1050	47
	90	260	115	155	250	1315	950	51
	120	260	110	150	255	1510	900	48
	60	280	105	130	190	1470	970	51
	90	280	115	150	215	1575	945	55
	120	280	130	165	235	1570	880	63
A3-102	60	240	120	175	300	1560	980	58
	90	240	125	180	305	1570	970	68
	120	240	135	185	315	1830	955	70
	60	260	150	190	315	2005	935	80
	90	260	155	200	380	1910	890	78
	120	260	165	215	530	2070	830	78
	60	280	180	250	820	2110	750	86
	90	280	185	255	940	2200	735	84
	120	280	175	245	850	2070	710	78
A2d-2	60	240	120	175	330	1560	970	58
	90	240	120	170	325	1670	980	59
	120	240	130	175	325	1680	965	63
	60	260	165	215	435	2070	875	75
	90	260	165	210	535	1950	800	76
	120	260	170	220	630	1850	750	78
	60	280	180	240	875	2145	750	82
	90	280	180	245	875	2085	735	81
	120	280	180	250	940	2120	715	79

TABLE 60

ADDITIONAL COMPOUNDS DESIGNED TO EVALUATE MERAC

Formulation No.	A3-119	A2d-3	A3-105	A2d-4
Neoprene 750	70.0	70.0	80.0	80.0
Neoprene 400	30.0	30.0	-	-
Neoprene 571	-	-	20.0	20.0
Zinc Oxide	5.0	5.0	5.0	5.0
Neozone 'D'	2.0	2.0	2.0	2.0
N.B.C.	3.0	3.0	3.0	3.0
Accelerator 833	1.0	-	1.0	-
Merac	-	1.0	-	1.0
Sunaptic Acid	1.0	1.0	1.0	1.0
Aquarex SMO	0.5	0.5	0.5	0.5
Butyl Oleate	25.0	25.0	-	-
Dibutyl Sebacate	-	-	6.25	6.25

TABLE 61

PHYSICAL PROPERTIES OF COMPOUNDS A3-119, A2d-3, A3-105, AND A2d-4 TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
A3-119	60	240	85	165	340	810	835	42
	90	240	95	165	335	895	850	48
	120	240	105	175	355	845	825	40
	60	260	105	170	415	1250	880	45
	90	260	115	195	435	1380	865	55
	120	260	110	180	445	1255	850	47
	60	280	125	195	455	1330	870	54
	90	280	130	215	510	1540	860	71
	120	280	130	230	630	1530	845	65
A2d-3	60	240	110	195	420	765	760	39
	90	240	115	200	435	1110	830	44
	120	240	130	195	435	690	755	57
	60	260	135	215	530	1320	850	54
	90	260	135	220	530	1345	845	57
	120	260	135	220	530	1350	840	62
	60	280	150	240	590	1445	850	59
	90	280	150	270	665	1600	840	73
	120	280	155	260	650	1565	825	68
A3-105	60	240	110	135	250	1230	1080	61
	90	240	115	145	245	1520	1105	60
	120	240	130	170	240	1590	1060	72
	60	260	125	165	230	1765	1070	67
	90	260	130	170	245	1875	1080	82
	120	260	145	175	245	2315	1070	82
	60	280	135	165	230	1950	1000	62
	90	280	140	175	250	1870	935	69
	120	280	140	180	300	1930	880	69
A2d-4	60	240	115	170	325	1380	1040	63
	90	240	140	180	320	1585	935	63
	120	240	140	180	320	1645	905	64
	60	260	135	185	320	1675	890	64
	90	260	150	185	325	1675	880	70
	120	260	150	190	325	1685	870	66
	60	280	140	175	280	1620	870	53
	90	280	145	180	285	1590	850	53
	120	280	145	185	305	1840	845	72

TABLE 62

PHYSICAL PROPERTIES OF COMPOUNDS A3-119 AND A2d-3 TESTED AT -70°C AND OF COMPOUNDS A3-105 AND A2d-4 TESTED AT -50°C

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Test Temp. (°C)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A3-119	60	240	-70	1935	3395	-	3930	440
	90	240	-70	1825	3440	-	4480	480
	120	240	-70	1890	3490	-	4420	450
	60	260	-70	2130	4135	-	5225	490
	90	260	-70	2195	4090	-	4975	470
	120	260	-70	2095	4010	-	4880	450
	60	280	-70	1900	3855	-	4695	480
	90	280	-70	2680	4820	-	5095	420*
	120	280	-70	2980	-	-	4710	360*
A2d-3	60	240	-70	1980	3585	-	4680	460
	90	240	-70	1955	3700	-	4740	500
	120	240	-70	2155	3855	-	4630	470
	60	260	-70	2090	3750	-	5030	490
	90	260	-70	2335	4235	-	5215	460
	120	260	-70	2120	3990	-	5350	490
	60	280	-70	2240	3290	-	4910	520
	90	280	-70	2570	3730	-	4920	500
	120	280	-70	2815	4660	-	5655	490
A3-105	60	240	-50	1040	2005	-	4360	590
	90	240	-50	925	1755	-	4330	580
	120	240	-50	1020	1910	-	4380	590
	60	260	-50	1000	1920	4575	4890	610*
	90	260	-50	1025	1780	4290	4730	620*
	120	260	-50	1315	1900	4480	5345	630*
	60	280	-50	1720	2585	5870	5870	600*
	90	280	-50	1650	3320	6790	6900	610*
	120	280	-50	2415	3575	-	5640	550*
A2d-4	60	240	-50	840	1525	4470	4520	630
	90	240	-50	900	2120	-	4880	590
	120	240	-50	1005	2320	-	4700	590
	60	260	-50	1510	2720	-	5050	560
	90	260	-50	1600	2840	-	5100	550
	120	260	-50	1625	3050	-	5520	530
	60	280	-50	1505	2200	-	4930	580
	90	280	-50	1390	1500	3175	4812	660
	120	280	-50	1785	2785	6310	6310	600*

* Cold Flow

FACTUAL DATA (continued)

TASK A, Phase 2, Part D (continued)

A study of these results shows that Merac produces a very flat-curing compound which is less susceptible to variations in temperature and time and reaches optimum physical properties at lower cures than does Accelerator 833. This appears to be true for all the compounds tested.

In addition, Merac has slightly superior low temperature characteristics than does Accelerator 833 showing less tendency toward cold flow although the breaking elongation is in general no greater.

It would appear from these results that Merac is worthy of further investigation, and balloons for flight testing were made from a compound containing this accelerator. The results are recorded in Task A, Phase 4.

It has been customary throughout this study to use one part of accelerator for 100 parts of neoprene in all experimental formulae. It was considered of interest to determine the effect of varying the amount of accelerator, and two accelerators (Merac and Accelerator 833) were selected for this investigation.

Right compounds were prepared, four containing 0.5, 1.0, 2.0, and 3.0 parts of Merac, respectively, and four containing similar parts of Accelerator 833. The formulations for these compounds are given in Table 63.

Plates were dipped from these compounds according to standard procedure and cured for 60, 90, and 120 minutes at 240°F., 260°F., and 280°F. Physical properties were determined at room temperature and at -40°C at those cures which are normally considered optimum for each of these compounds with one part of accelerator. The results of these tests are given in Tables 64, 65 and 66.

A study of the tables confirms that Merac is an extraordinarily flat-curing accelerator. The room-temperature physical properties show virtually no change with 0.5, 1.0, 2.0, or 3.0 parts in the compound or at any cure time and temperature tested other than the 240°F. cures. This is unquestionably a very desirable property in a balloon compound because of the difficulties associated with exposing the whole surface of a balloon to the same temperature for the same time. At -40°C., however, increasing the amount of Merac results in improved elongation.

FACTUAL DATA (continued)

TASK A, Phase 2, Part D (continued)

TABLE 63

FORMULATIONS OF COMPOUNDS CONTAINING VARYING QUANTITIES OF MERAC AND ACCELERATOR 833

Formulation No.	A2d-5	A2d-6	A2d-7	A2d-8	A2d-9	A2d-10	A2d-11	A2d-12
Neoprene 750	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0
Neoprene 571	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Zinc Oxide	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Neozone 'D'	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
N.B.C.	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Sunaptic Acid	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Aquarex SMO	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Dibutyl Sebacate	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25
Merac	0.5	1.0	2.0	3.0	-	-	-	-
Accelerator 833	-	-	-	-	0.5	1.0	2.0	3.0

FACTUAL DATA (continued)

TASK A, Phase 2, Part D (continued)

TABLE 64

PHYSICAL PROPERTIES OF COMPOUNDS A2d-5, A2d-6, A2d-7, AND A2d-8
TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
A2d-5	60	240	120	185	315	1385	900	67
	90	240	125	185	335	1630	900	62
	120	240	135	205	390	1750	870	70
	60	260	155	200	420	2140	880	62
	90	260	155	210	430	2090	880	64
	120	260	165	220	435	2135	860	64
	60	280	170	215	385	1815	860	72
	90	280	165	215	405	2230	865	77
	120	280	160	220	390	2210	870	71
A2d-6	60	240	135	195	375	1600	930	55
	90	240	155	210	415	1885	875	65
	120	240	160	215	420	1885	865	64
	60	260	160	230	425	2045	880	62
	90	260	160	215	420	1980	870	68
	120	260	160	225	425	2100	870	67
	60	280	155	215	400	1920	880	63
	90	280	160	215	400	2020	870	77
	120	280	155	210	405	1870	850	82
A2d-7	60	240	145	210	395	1700	880	71
	90	240	150	210	415	1830	860	84
	120	240	150	215	420	1950	850	76
	60	260	155	215	430	1970	870	59
	90	260	160	215	430	2050	860	57
	120	260	155	220	430	2115	860	59
	60	280	150	200	390	1975	880	72
	90	280	140	205	385	2100	875	69
	120	280	140	200	395	2015	860	68
A2d-8	60	240	140	205	380	1735	880	67
	90	240	140	205	410	1730	860	70
	120	240	150	210	420	1830	845	70
	60	260	140	210	420	2085	870	62
	90	260	140	220	425	2085	870	62
	120	260	140	220	420	2115	880	58
	60	280	140	200	395	1685	875	62
	90	280	140	200	390	1840	860	62
	120	280	140	200	385	1700	840	62

FACTUAL DATA (continued)

TASK A, Phase 2, Part D (continued)

TABLE 65

PHYSICAL PROPERTIES OF COMPOUNDS A2d-9, A2d-10, A2d-11, AND A2d-12
TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
A2d-9	60	240	135	185	320	1500	970	63
	90	240	155	200	355	1650	910	63
	120	240	160	205	365	1725	870	62
	60	260	155	210	365	1790	890	66
	90	260	160	220	385	1800	875	65
	120	260	165	225	370	1915	870	64
	60	280	150	185	305	1700	870	63
	90	280	155	185	335	1890	880	68
	120	280	150	185	330	1780	870	61
A2d-10	60	240	90	130	220	1430	1140	57
	90	240	110	150	240	1600	1075	58
	120	240	125	170	280	1750	975	56
	60	260	135	180	315	1920	960	60
	90	260	140	180	325	1930	940	60
	120	260	145	180	330	1990	935	58
	60	280	145	190	295	2030	980	68
	90	280	150	200	325	2100	940	73
	120	280	155	200	335	2115	900	73
A2d-11	60	240	70	125	230	1340	1155	47
	90	240	85	130	235	1535	1135	47
	120	240	100	140	245	1545	1100	50
	60	260	110	145	195	1765	1170	50
	90	260	110	135	200	1635	1140	51
	120	260	120	150	205	1845	1125	51
	60	280	130	160	205	1890	1210	62
	90	280	135	170	230	2200	1080	75
	120	280	140	180	290	2315	970	80
A2d-12	60	240	75	110	190	1350	1235	50
	90	240	85	115	210	1370	1185	55
	120	240	90	125	215	1505	1145	55
	60	260	105	135	175	1885	1200	58
	90	260	115	135	190	1860	1170	63
	120	260	120	140	190	1955	1170	58
	60	280	115	140	180	1780	1260	62
	90	280	120	140	180	1845	1240	59
	120	280	130	160	220	1915	1090	62

FACTUAL DATA (continued)

TASK A, Phase 2, Part D (continued)

TABLE 66

PHYSICAL PROPERTIES OF COMPOUNDS A2d-5 THROUGH A2d-12
TESTED AT -40°C.

Compound No.	Cure Time (mins)	Cure Temp. (°F.)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A2d-5	90	260	285	660	3390	3685	610
A2d-6	90	260	265	510	3545	4100	650
A2d-7	90	260	230	490	2880	4950	670
A2d-8	90	260	210	485	2625	5050	700
A2d-9	120	280	280	1125	5000	5340	610
A2d-10	120	280	255	575	3820	4540	630
A2d-11	120	280	265	510	2525	4500	680
A2d-12	120	280	230	485	2350	3675	700

FACTUAL DATA (continued)

TASK A, Phase 2, Part D (continued)

The behavior of Accelerator 833 is unexpected and most interesting. While this accelerator is relatively flat curing at any one concentration, variations in the amount of accelerator produce considerable variations in physical characteristics. It is particularly noteworthy that increasing the amount of accelerator in the compound substantially increases the room-temperature elongation and reduces the modulus.

A similar set of compounds based on a dual-purpose compound (A3-104) was now prepared, the amount of accelerator being varied from 1.0 to 3.0 parts. The formulations of these compounds are given in Table 67.

Plates were dipped according to standard procedure and cured for 60, 90, and 120 minutes at 250°F., it having been previously established that this is the optimum curing temperature for this type of compound. Physical properties were determined at room temperature and at -70°C., and the results of these tests are given in Tables 68 and 69.

A study of these tables shows that the extremely flat-curing characteristics of Merac are equally apparent when this accelerator is used in a dual-purpose compound. However, at 70°C., there is no comparable improvement in elongation as was shown at -40°C. for a day-flight compound.

In the case of the compounds containing Accelerator 833, the elongation at -70°C. is virtually independent of the amount of accelerator. In the case of the compounds containing Merac, there is a possibly a slight improvement as the amount of accelerator increases. This is, however, of no significant value as far as balloon flights are concerned.

According to information received from du Pont, it is possible to compound Neoprene 750 using Thiocarbanilide as the accelerator and produce films which will develop elongations of 1000% without curing at elevated temperatures.

Two compounds were, therefore, prepared, one of which contained no plasticizer and the other 5 parts of plasticizer and 10 parts of Mistron Vapor in order to provide a higher modulus. It was felt that this accelerator would tend to show very low modulus characteristics in the standard test formula. These formulations are given in Table 70.

FACTUAL DATA (continued)

TASK A, Phase 2, Part D (continued)

TABLE 67

FORMULATIONS OF DUAL-PURPOSE COMPOUNDS CONTAINING VARYING QUANTITIES OF MERAC AND ACCELERATOR 833

Formulation No.	A2d-13	A2d-14	A2d-15	A2d-16	A2d-17	A2d-18
Neoprene 750	80.0	80.0	80.0	80.0	80.0	80.0
Neoprene 571	10.0	10.0	10.0	10.0	10.0	10.0
Neoprene 735	10.0	10.0	10.0	10.0	10.0	10.0
Zinc Oxide	2.5	2.5	2.5	2.5	2.5	2.5
Neozone 'D'	1.0	1.0	1.0	1.0	1.0	1.0
N.B.C.	3.0	3.0	3.0	3.0	3.0	3.0
Sunaptic Acid	1.0	1.0	1.0	1.0	1.0	1.0
Aquarex SMO	0.5	0.5	0.5	0.5	0.5	0.5
Dibutyl Sebacate	5.0	5.0	5.0	5.0	5.0	5.0
Butyl Oleate	22.5	22.5	22.5	22.5	22.5	22.5
Sulphur	2.0	2.0	2.0	2.0	2.0	2.0
Accelerator 833	1.0	2.0	3.0	-	-	-
Merac	-	-	-	1.0	2.0	3.0

FACTUAL DATA (continued)

TASK A, Phase 2, Part D (continued)

TABLE 68

PHYSICAL PROPERTIES OF COMPOUNDS A2d-13 THROUGH A2d-18
TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
A2d-13	60	250	95	140	290	1405	830	35
	90	250	100	155	300	1450	830	35
	120	250	95	150	295	1430	810	40
A2d-14	60	250	95	135	270	1350	855	40
	90	250	100	145	275	1570	850	45
	120	250	100	155	290	1600	840	45
A2d-15	60	250	95	140	240	1475	885	40
	90	250	100	145	285	1620	865	40
	120	250	100	155	295	1670	845	45
A2d-16	60	250	95	145	280	1370	815	40
	90	250	100	150	280	1470	820	40
	120	250	100	150	275	1440	815	35
A2d-17	60	250	95	150	280	1335	815	40
	90	250	105	150	280	1440	815	40
	120	250	100	150	290	1450	815	40
A2d-18	60	250	100	140	260	1400	820	40
	90	250	105	140	280	1400	815	40
	120	250	100	150	280	1440	815	45

FACTUAL DATA (continued)

TASK A, Phase 2, Part D (continued)

TABLE 69

PHYSICAL PROPERTIES OF COMPOUNDS A2d-13 THROUGH A2d-18
TESTED AT -70°C

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A2d-13	60	250	1090	2235	-	3380	520
	90	250	1275	2830	-	4235	500
	120	250	1680	3040	-	3840	480
A2d-14	60	250	1300	2575	-	4035	520
	90	250	1475	2710	-	4100	500
	120	250	1445	2660	-	3740	490
A2d-15	60	250	1085	2400	-	3940	520
	90	250	1150	2660	-	3920	520
	120	250	1200	2785	-	3555	480
A2d-16	60	250	1180	1860	-	2720	500
	90	250	1370	2470	-	4230	530
	120	250	1550	3000	-	4635	530
A2d-17	60	250	1300	2585	-	4100	510
	90	250	1530	2700	-	4290	520
	120	250	1780	3100	-	4415	510
A2d-18	60	250	1410	2710	-	4590	540
	90	250	1210	2655	-	4360	520
	120	250	1880	2800	-	4595	520

FACTUAL DATA (continued)

TASK A, Phase 2, Part D (continued)

TABLE 70

FORMULATIONS OF COMPOUNDS CONTAINING THIOCARBANILIDE

Formulation No.	A2d-19	A2d-20
Neoprene 750	100.0	100.0
Zinc Oxide	5.0	5.0
Neozone 'D'	2.0	2.0
N.B.C.	3.0	3.0
Thiocarbanilide	2.0	2.0
Sunaptic Acid	1.0	1.0
Dibutyl Sebacate	-	5.0
Mistron Vapor	-	10.0

TABLE 71

PHYSICAL PROPERTIES OF COMPOUNDS A2d-19 AND A2d-20
TESTED AT ROOM TEMPERATURE AND AT -40°C

Compound No.	Test Temp. (°C)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A2a-19	+20	70	95	170	410	1650	1180
	-40	70	740	1000	2900	2900	600
A2a-20	+20	70	125	235	465	1250	955
	-40	70	445	1110	-	1890	580

FACTUAL DATA (continued)

TASK A, Phase 2, Part D (continued)

Plates were dipped according to standard procedure and allowed to dry at room temperature. Physical characteristics were determined at room temperature and at -40°C., and the results of these tests are given in Table 71.

A study of these results indicates that this curing system may be of considerable interest. Elimination of high temperature curing is apt to result in more uniformity in physical properties throughout the balloon.

The characteristics of both compounds, particularly in view of the extremely low plasticizer content in each case, are quite satisfactory; and the relatively high modulus is also interesting.

It is, however, felt that a careful study of the aging characteristics of these compounds must be undertaken before proceeding to the manufacture of balloons for flight.

Part E: Polymers other than Neoprene

Poly-isoprene, which is a synthetic form of natural rubber with the same chemical structure, has recently been made available by Shell Chemicals in latex form.

The use of natural latex in meteorological balloons except for night-flight was discontinued during World War II when a successful neoprene balloon was developed by Kaysam. Subsequently, a successful neoprene night-flight balloon was also developed by Kaysam, and the use of natural latex was abandoned entirely. One reason for this was the necessity for eliminating reliance on an overseas source for a vital material.

However, natural latex possesses certain inherent advantages over neoprene, in particular its much superior freeze resistance. With a domestic source of poly-isoprene latex now available, it would be wise to evaluate this material as a potential meteorological balloon compounding ingredient.

A preliminary investigation of poly-isoprene latex from Shell Chemical Corporation was carried out. Although this material is claimed by the manufacturer to behave in a manner similar to natural latex, it was found to be much more critical.

FACTUAL DATA (continued)

TASK A, Phase 2, Part E (continued)

The mechanical and chemical stability of the latex system is much less than that of natural latex or of neoprene latex and calls for much more careful compounding and subsequent handling. The initial compound made according to the recommendations of the supplier showed extremely low tensile strength, excessive permanent set, and a tendency for the stretched film to relax substantially over a small area which became extremely thin compared with the rest of the film.

Increasing the sulphur content to a minimum of 2.5 parts resulted in a firmer gel and a cured film which no longer exhibited the characteristics described above. However, the maximum tensile strength obtainable was 1600 psi with an elongation of 1100%. This falls far below the manufacturer's claim of tensile strength in the order of 5500 psi, although the elongation is similar to the claim of 1050%.

The latex compound which produced a film having even this tensile strength was extremely unstable showing a rapid rise of viscosity after compounding, a substantial fall in pH, and a strong tendency to flocculate upon agitation.

The strength of the wet gel was poor and showed the same tendency as did the uncured film to relax in one small area and then to continue stretching until it ruptured without developing sufficient modulus for the rest of the gel to expand.

Discussion with representatives of Shell Chemical Corporation resulted in the suggestion that this sample of poly-isoprene latex was defective; therefore, a further sample of this material was obtained.

Three compounds were prepared, one of which was that recommended by the supplier and is designated A2e-1. The remaining two compounds contained changes in the acceleration system, and these formulae are given in Table 72.

Plates were dipped according to standard procedure and cured for the time and at the temperature recommended by the supplier. At the same time, a small balloon form was dipped, and the gels stripped and inflated. The gel obtained with compound A2e-2 proved to be so weak and to distort to such a degree on stripping that it was of no value, and no physical properties were determined. The properties shown by compounds A2e-1 and A2e-3 are given in Table 73.

FACTUAL DATA (continued)

TASK A. Phase 2. Part E (continued)

TABLE 72

FORMULATIONS OF COMPOUNDS BASED ON SHELL'S POLY-ISOPRENE LATEX 700

Formulation No.	A2e-1	A2e-2	A2e-3
Poly-isoprene 700	100.0	100.0	100.0
Zinc Oxide	2.0	2.0	2.0
Sulphur	2.0	2.0	2.0
Ethyl Zimate	1.25	-	-
Merac	-	1.0	-
Butyl Zimate	-	-	1.0
Antioxidant	1.0	1.0	1.0

TABLE 73

PHYSICAL PROPERTIES OF COMPOUNDS A2e-1 AND A2e-3
TESTED AT +20°C

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A2e-1	60	212	85	125	170	2000	1300
	60	250	70	105	185	2465	1150
A2e-3	60	212	110	215	465	2020	920
	60	250	100	210	525	2280	910

FACTUAL DATA (continued)

TASK A, Phase 2, Part E (continued)

A study of these results shows that the physical properties are generally unsatisfactory and do not compare with those claimed by the manufacturer. According to the supplier, compound A2e-1 should have a tensile strength of 5950 psi, and an elongation of 97%.

The balloon gels which were obtained from these two compounds were also completely unsatisfactory. It was impossible to strip the gels without severe distortion and the creation of weak areas unless the gels were leached on the form in hot water for 60 minutes.

After such leaching, the gel from compound A2e-1 still expanded very unevenly although it was possible to obtain a fairly spherical expanded gel. However, upon deflation, the balloon recovered to such an extent that it was very little longer than when originally stripped. In addition, there were wrinkled areas corresponding to the outside of the flutes.

The gels from compound A2e-3 also showed almost 100% recovery to their original length, and it is to be presumed that the hot water leach has, in effect, cured the balloon and this is why the gel can be stripped without distortion.

Further discussions with representatives of Shell Chemical Corporation did little to encourage additional work with poly-isoprene. However, it was decided that this research was incomplete without the evaluation of a poly-isoprene type; and, therefore, work was started with natural latex.

The major problem associated with the use of natural latex in meteorological balloon compounds is its poor ozone resistance. Three compounds were, therefore, prepared incorporating varying amounts of N.B.C. The formulations for these compounds are given in Table 74.

Plates were dipped from these compounds according to standard procedure and cured for 60 minutes at 230°F. Physical properties were determined at room-temperature and at -40°C. and -50°C., and the results of these tests are given in Table 75.

A study of these results shows that all three compounds have very similar physical properties which appear to be very satisfactory for meteorological balloons. However, it was observed that N.B.C. in a natural latex compound results in an extremely rapid pre-cure, the compound becoming unusable in three days.

FACTUAL DATA (continued)

TASK A, Phase 2, Part E (continued)

TABLE 74

FORMULATIONS OF NATURAL LATEX COMPOUNDS

Formulation No.	A2e-4	A2e-5	A2e-6
Natural Latex	100.00	100.00	100.00
KOH	0.25	0.25	0.25
Aquarex 'D'	0.10	0.10	0.10
Zinc Oxide	0.50	0.50	0.50
Neozone 'D'	2.00	2.00	2.00
N.B.C.	1.00	2.00	3.00
Merac	1.50	1.50	1.50
Sulphur	1.00	1.00	1.00

ACTUAL DATA (continued)

ASK A, Phase 2, Part E (continued)

TABLE 75

PHYSICAL PROPERTIES OF COMPOUNDS A2e-4, A2E-5, AND A2e-6
TESTED AT ROOM-TEMPERATURE, -40°C, AND -50°C.

Compound No.	Test Temp. (°C.)	Cure Time (mins)	Cure Temp. (°F.)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elong. at Break (%)	Tear Strength (lbs/in)
A2e-4	+20	60	230	110	155	390	2850	985	162
	-40	60	230	120	190	665	1335*	850*	
	-50	60	230	130	220	725	1490*	800*	
A2e-5	+20	60	230	90	160	360	2035	985	82
	-40	60	230	115	185	650	1420*	850*	
	-50	60	230	125	210	715	1510*	825*	
A2e-6	+20	60	230	95	185	370	2330	970	90
	-40	60	230	120	205	690	1780*	840*	
	-50	60	230	120	235	770	1595*	830*	

*Samples reached limit of test equipment without breaking.

FACTUAL DATA (continued)

TASK A, Phase 2, Part E (continued)

A further series of natural latex compounds was, therefore, designed in which different types of antiozonants well-known to be compatible with natural latex, were incorporated. The formulations for these compounds are given in Table 76.

Plates were dipped according to standard procedure, and films were cured for 60 and 90 minutes at 212°F. Physical properties were determined at room temperature, and the appearance of the films after exposure to ultra-violet radiation in air (which creates ozone) was observed. The results of these tests are given in Table 77.

It is immediately apparent from a study of these results that the comditions of test for ozone resistance are much too severe, or else even the improved antiozonants now available are completely inadequate to provide the necessary protection. The physical properties of compounds A2e-7 and A2e-11, otherwise, appear to be perfectly satisfactory; and in order to determine the ozone resistance in operating conditions, balloons should now be made and flight tested. Such balloons should be designed to reach an altitude of 100,000 feet in order to be certain that the maximum atmospheric ozone concentration will be encountered in flight.

It was suggested at this time that Barak, supplied by E. I. du Pont and described as Dibutyl Ammonium Oleate, might be of value in curing poly-isoprene latex compounds: The following two compounds were, therefore, prepared:

	A2e-12	A2e-13
Poly-isoprene 700	100.0	100.0
Zinc Oxide		2.0
Sulphur	2.0	2.0
Ethyl-zimate	0.5	0.5
Barak	0.75	0.75
Antioxidant	1.0	1.0

Plates were dipped according to standard procedure. One set was leached for 30 minutes in cold water, and one set for 30 minutes in hot water. The films were cured for 15 minutes and 30 minutes at 212°F., and physical properties were determined at room temperature. The results of these tests are given in Table 78.

FACTUAL DATA (continued)

TASK A. Phase 2. Part E (continued)

TABLE 76

FORMULATIONS OF NATURAL LATEX COMPOUNDS

Formulation No.	A2e-7	A2e-8	A2e-9	A2e-10	A2e-11
Natural Latex	100.00	100.00	100.00	100.00	100.00
KOH	0.25	0.25	0.25	0.25	0.25
Aquarex 'D'	0.10	0.10	0.10	0.10	0.10
Zinc Oxide	0.25	0.25	0.25	0.25	0.25
Sulphur	0.75	0.75	0.75	0.75	0.75
Neozone 'D'	1.00	1.00	1.00	1.00	-
Santowhite Crystals	2.00	5.00	2.00	2.00	2.00
Agerite DPPD	-	-	2.00	4.00	2.00
GL-5 Emulsion	2.00	2.00	2.00	2.00	2.00
Setsit 51	1.00	1.00	1.00	1.00	1.00

FACTUAL DATA (continued)

TASK A, Phase 2, Part E (continued)

TABLE 77

PHYSICAL PROPERTIES OF NATURAL LATEX COMPOUND A2e-7 THROUGH A2e-11 TESTED AT ROOM-TEMPERATURE AND EXPOSED TO ULTRA-VIOLET RADIATION

Compound No.	Cure Time (mins)	Cure Temp. (°F.)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elong. at Break (%)	Appearance after Exposed to UV 20 mins.
A2e-7	60 90	212 212	165 150	205 210	370 365	2405 2215	1020 970	very severely attacked
A2e-8	60 90	212 212	155 125	270 210	595 330	2800 1480	950 960	very severely attacked
A2e-9	60 90	212 212	200 185	285 315	715 860	3045 3610	840 850	very severely attacked
A2e-10	60 90	212 212	200 170	325 310	850 900	3750 3585	855 845	very severely attacked
A2e-11	60 90	212 212	140 125	175 190	410 370	2390 2145	970 985	very severely attacked

FACTUAL DATA (continued)

TASK A, Phase 2, Part E (continued)

TABLE 78

PHYSICAL PROPERTIES OF POLY-ISOPRENE COMPOUND A2e-12 AND A2e-13 TESTED AT ROOM-TEMPERATURE

Compound No.	Leach Temp. (°F.)	Cure Time (mins)	Cure Temp. (°F.)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A2e-12	50	15	212	55	50	50	55	1585
	50	30	212	60	60	65	85	1045
	180	15	212	55	45	45	65	1900
	180	30	212	55	45	45	75	1815
A2e-13	50	15	212	75	115	145	2795	1345
	50	30	212	90	135	200	2645	1185
	180	15	212	75	115	155	2235	1370
	180	30	212	75	115	190	2670	1195

TASK A, Phase 2, Part E (continued)

A study of these results shows that compound A2e-12 has the same chewing-gum characteristics originally encountered with this material. Extremely high elongations can be attained, but no tensile strength is developed. Compound A2e-13, however, gives the best physical properties yet obtained with poly-isoprene. Apart from the rather low modulus, these physical properties are quite acceptable for a balloon film, the room-temperature elongation being impressively high.

This does not mean that balloons can be made by the gel expansion process from this material, but it does suggest that further work should be conducted with poly-isoprene.

Part F: Reinforcing Fillers

The use of carbon black confers excellent physical properties on a balloon film compound but is prejudicial to day flights because of its high infra-red radiation absorption. It was therefore decided to investigate Mistron Vapor, a very fine-particle-size talc, manufactured by The Sierra Talc Company.

Three compounds containing Mistron Vapor were prepared, the formulations of which are given in Table 79. Plates were dipped from these compounds according to standard procedure and cured for 60, 90, and 120 minutes at 280°F. Physical properties were determined at room-temperature and at -40°C., and the results of these tests are given in Table 80.

A study of these results shows that inclusion of Mistron Vapor in the compound results in a substantial increase in the modulus of the compound. The tensile strength is also increased, although to a lesser degree, and there is a relatively small loss in elongation.

At -40°C., there is an increase in the modulus at 200%, but the modulus at 400% and 600% and the tensile strength show relatively little change as does the elongation. It would appear, therefore, that Mistron Vapor can satisfactorily be used to increase the modulus of neoprene balloon compounds and that this characteristic might be of considerable value in the design of fast-rising balloon compounds.

Initial tests were made with zinc resinate obtained under the tradename of Zirex-DG-6566-01 from Newport Industries..

TABLE 79

FORMULATIONS OF COMPOUNDS CONTAINING MISTRON VAPOR

Formulation No.	A2f-1	A2f-2	A2f-3
Neoprene 750	80.0	80.0	80.0
Neoprene 571	20.0	20.0	20.0
Zinc Oxide	5.0	5.0	5.0
Neozone 'D'	2.0	2.0	2.0
N.B.C.	3.0	3.0	3.0
Accelerator 833	1.0	1.0	1.0
Sunaptic Acid	1.0	1.0	1.0
Aquarex SMO	0.5	0.5	0.5
Dibutyl Sebacate	6.25	6.25	6.25
Mistron Vapor	5.0	10.0	15.0

FACTUAL DATA (continued)

TASK A, Phase 2, Part F (continued)

TABLE 80

PHYSICAL PROPERTIES OF COMPOUNDS A3-105, A2f-1, A2f-2, AND A2f-3 TESTED AT ROOM TEMPERATURE AND AT -40°C

Compound No.	Test Temp. (°C)	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elong. at Break (%)	Tear Strength (lbs/in)
A3-105	+20	60	280	125	170	280	2020	940	71
	+20	90	280	135	175	300	2150	925	74
	+20	120	280	135	185	325	2200	900	72
A2f-1	+20	60	280	180	265	520	2165	920	91
	+20	90	280	185	270	580	2340	900	91
	+20	120	280	195	275	620	2440	870	100
A2f-2	+20	60	280	210	310	625	2200	900	112
	+20	90	280	215	315	640	2430	920	107
	+20	120	280	220	335	725	2430	880	107
A2f-3	+20	60	280	265	415	870	2700	920	133
	+20	90	280	270	440	900	2790	875	138
	+20	120	280	275	445	900	2600	865	124
A3-105	-40	60	280	420	760	3820	4680	650	-
	-40	90	280	480	820	4000	4410	620	-
	-40	120	280	510	810	3920	4380	620	-
A2f-1	-40	60	280	510	850	4200	4370	610	-
	-40	90	280	535	1020	3990	3990	600	-
	-40	120	280	690	1450	4100	4230	610	-
A2f-2	-40	60	280	620	1760	4160	4400	610	-
	-40	90	280	680	2100	5300	5525	620	-
	-40	120	280	760	1840	3960	3960	600	-
A2f-3	-40	60	280	880	2220	4390	5100	620	-
	-40	90	280	1010	1890	-	5370	590	-
	-40	120	280	1020	2140	-	5260	590	-

increase the modulus of neoprene balloon compounds and that this characteristic might be of considerable value in the design of fast-rising balloon compounds.

Initial tests were made with zinc resinate obtained under the tradename of Zirex-BG-6566-01 from Newport Industries. This material contains approximately 10% zinc and was found to be soluble in Dibutyl Sebacate to the extent of 15 parts per hundred.

In a compound containing even as much as 25 parts of Dibutyl Sebacate it would, therefore, only be possible to incorporate about 4 parts of zinc resinate, which means that the zinc content of the compound would be 0.4%. This quantity is known to be too little.

The melting point of zinc resinate is too high to enable a hot emulsion to be made, and the use of a volatile solvent was not considered suitable for preparing emulsions for use in balloon compounds because of the extreme danger of porosity in the vulcanized film.

In addition to the above, the resinous nature of the material renders the neoprene film extremely tacky. Since the purpose of using zinc resinate was to eliminate a solid dispersion of zinc oxide and replace it with an emulsion, there was no point in attempting to make a zinc resinate dispersion; and in view of the attendant problems and disadvantages, no further work is planned with this material.

Phase 3: Development of Formulations with Desirable Film Properties

Part A: High-Altitude Balloon Compounds

The bulk of the first quarter of this study was devoted to the evaluation of new polymers and improved antiozonants and antioxidants. Examination of the results obtained led to the following conclusions:

1. Neoprene 400 raises the modulus of balloon compounds sharply once a certain minimum quantity has been exceeded. At the same time it reduces breaking elongation. It also improves the ozone resistance.

2. Lytron 615 raises the modulus and has little effect on elongation. It substantially reduces ozone resistance.

3. Butyl Oleate reduces modulus, particularly of compounds containing Neoprene 571. It has much less effect on compounds containing Neoprene 400 and is still the most effective low-temperature plasticizer when used alone or in conjunction with Dibutyl Sebacate.

4. Agerite DPPD is a very effective antio-ozonant, being much superior to N.B.C. It is effective in the presence of Lytron 615 and also increases the modulus.

5. Wingstay 'T' reduces the modulus of neoprene compounds and increases the elongation.

6. Neoprene 400 and Neoprene 735 in conjunction yield low elongation compounds, and this combination has no value.

It can, therefore, be seen that there are now a number of additional tools available for creating the physical properties desired in meteorological balloon compounds. However, in almost every case, each of the materials listed above offers an improvement in characteristics which is coupled with an undesirable quality. Hence, compounds must be designed in an effort to retain the improvements while compensating for the disadvantages.

The following formulae were designed for high altitude day-flight balloons:

	A3-108	A3-109	A3-113
Neoprene 750	70.0	60.0	80.0
Neoprene 400	30.0	40.0	20.0
Zinc Oxide	5.0	5.0	6.0
Wingstay 'T'	2.0	3.0	2.0
Agerite DPPD	3.0	3.0	3.0
Accelerator 833	1.0	1.0	1.0
Sunaptic Acid	1.0	1.0	1.0
Aquarex SMO	0.5	0.5	0.5
Butyl Oleate	10.0	10.0	10.0

FACTUAL DATA (continued)

TASK A, Phase 3, Part A (continued)

Plates were dipped from these compounds according to standard procedure, and physical properties were determined at room temperature.

The results of these tests are given in Table 81.

A study of these results shows that of the three compounds, only A3-113 has room-temperature physical characteristics which appear to be satisfactory, both A3-108 and A3-109 having undesirably low room-temperature elongation.

Since one of the objectives in the design of these compounds was to improve the ozone resistance, the behavior of compound A3-113 in the ozone chamber was determined. Samples of A3-113 and A3-105 were exposed in the ozone chamber according to the standard procedure already established, and the time to rupture was determined. The results obtained were as follows:

Compound	Time to Rupture
A3-105	75 minutes
A3-113	55 minutes

This is in contradiction to the previously reported excellent performance of Agerite DPPD and Neoprene 400 in the ozone chamber (see Task A, Phase 2, Part C).

The only differences between A3-113 and A3-105 are the use of Neoprene 400 instead of Neoprene 571, the replacement of Neozone 'D' with Wingstay 'T', and the replacement of N.B.C. with Agerite DPPD. It would appear, therefore, that replacement of Neozone 'D' with Wingstay'T' is resulting in a serious fall in ozone resistance. Neozone 'D', however, cannot be considered an effective antiozonant; therefore, it must be concluded that Wingstay 'T' actually reduces the ozone resistance.

In order to verify this, a series of compounds was prepared in which the materials in question were compared. The formulations for these compounds are given in Table 82.

These compounds actually comprise three groups: A3a-1 to A3a-3 based on Neoprene 750 and Neoprene 571, A3a-5 to A3a-7 based on Neoprene 750 and Neoprene 400, A3a-8 to A3a-10 based on Neoprene 750, Neoprene 571, and Lytron 615. A3a-4 is an intermediate between the first and second groups.

FACTUAL DATA (CONTINUED)

TASK A PHASE 3 PART A (CONTINUED)

TABLE 81

PHYSICAL PROPERTIES OF COMPOUNDS A3-108, A3-109, AND A3-113
TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
A3-108	60	240	140	250	550	1190	855	64
	90	240	140	240	525	1400	895	72
	120	240	155	280	710	1630	840	72
	60	260	160	245	595	1580	880	61
	90	260	165	275	775	1660	815	81
	120	260	170	265	735	1960	850	81
	60	280	170	245	625	1805	845	72
	90	280	175	265	680	1940	860	80
	120	280	175	285	770	2120	835	85
A3-109	60	240	150	260	605	1165	830	56
	90	240	140	270	625	1260	835	76
	120	240	145	280	655	1490	850	73
	60	260	170	310	750	1675	850	81
	90	260	190	310	770	1925	845	76
	120	260	175	310	755	1820	855	82
	60	280	180	310	780	1935	845	106
	90	280	180	320	780	2065	845	104
	120	280	180	325	820	2205	860	104
A3-113	60	240	70	125	290	850	945	33
	90	240	85	155	320	1110	955	43
	120	240	85	150	315	1190	955	48
	60	260	95	140	300	1235	940	48
	90	260	105	160	330	1500	910	53
	120	260	110	165	325	1505	880	53
	60	280	115	165	275	1735	935	53
	90	280	120	165	345	1800	915	53
	120	280	145	185	385	1935	900	63

FACTUAL DATA (CONTINUED)

TASK A PHASE 3 PART A (CONTINUED)

TABLE 82

FORMULATIONS DESIGNED TO STUDY OZONE RESISTANCE OF COMPOUNDS WITH & WITHOUT WINGSTAY 'T'

Formulation No.	A3a-1	A3a-2	A3a-3	A3a-4	A3a-5	A3a-6	A3a-7	A3a-8	A3a-9	A3a-10
Neoprene 750	80.00	80.00	80.00	80.00	60.00	60.00	60.00	80.00	80.00	80.00
Neoprene 571	20.00	20.00	20.00	-	-	-	-	20.00	20.00	20.00
Neoprene 400	-	-	-	20.00	40.00	40.00	40.00	-	-	-
Lytron 615	-	-	-	-	-	-	-	15.00	15.00	15.00
Zinc Oxide	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Neozone 'D'	2.00	-	-	-	2.00	-	-	2.00	2.00	-
Wingstay 'T'	-	2.00	2.00	2.00	-	2.00	2.00	-	-	2.00
N.B.C.	3.00	3.00	-	-	3.00	3.00	-	3.00	-	-
Agerite DPPD	-	-	3.00	3.00	-	-	3.00	-	3.00	3.00
Accelerator 833	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Sunaptic Acid	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Aquarex SMO	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Dibutyl Sebacate	6.25	6.25	6.25	-	-	-	-	6.25	6.25	6.25
Butyl Oleate	-	-	-	10.00	10.00	10.00	10.00	-	-	-

FACTUAL DATA (continued)

TASK A, Phase 3, Part A (continued)

Samples were exposed in the ozone chamber at 200% elongation and to an ozone concentration of 80 parts per million, and the time to rupture was determined. The results of these tests are recorded in Table 83.

A study of these results shows that in each group, replacement of Neozone 'D' by Wingstay 'T' results in a sharp reduction in resistance to ozone. Replacement of N.B.C. by Agerite DPPD always results in an improvement in ozone resistance, this improvement being sufficient to offset the effect of Wingstay 'T'. However, the net result of replacing Neozone 'D' by Wingstay 'T' and N.B.C. by Agerite DPPD is to produce a compound with almost identical physical characteristics, including resistance to ozone.

It has generally been found that replacement of N.B.C. with Agerite DPPD results in a compound with lower elongation, and it was considered that Wingstay 'T' should offset this undesirable condition without affecting the improved ozone resistance. Since this has now been demonstrated to be incorrect, compounds were prepared based on A3-105 in which the N.B.C. was replaced with Agerite DPPD, this being the only change. The formulations of these compounds are given in Table 84.

Plates were dipped from these compounds according to standard procedure and cured for 60, 90, and 120 minutes at 240°F., 260°F., and 280°F. The physical characteristics, including ozone resistance, were determined at room temperature, and the results of these tests are given in Table 85. The physical characteristics of compound A3-105 are also given for comparison.

A study of these results shows that 2 parts of Agerite DPPD gives protection against ozone about equal to that of 3 parts of N.B.C. and that 3 parts of Agerite DPPD are necessary to provide substantially longer life. By reducing the cure temperature, physical characteristics approximating those of compound A3-105 cured at 280°F can be obtained.

TABLE 83

OZONE RESISTANCE OF COMPOUNDS CONTAINING WINGSTAY 'T'

Formulation No.	Contains Neozone 'D'	Contains Wingstay 'T'	Contains N.B.C.	Contains DPPD	Time to Rupture
A3a-1	yes	no	yes	no	75 mins.
A3a-2	no	yes	yes	no	12 mins.
A3a-3	no	yes	no	yes	85 mins.
A3a-4	no	yes	no	yes	55 mins.
A3a-5	yes	no	yes	no	75 mins.
A3a-6	no	yes	yes	no	15 mins.
A3a-7	no	yes	no	yes	70 mins.
A3a-8	yes	no	yes	no	20 mins.
A3a-9	yes	no	no	yes	85 mins.
A3a-10	no	yes	no	yes	13 mins.

TABLE 84

FORMULATIONS OF COMPOUNDS CONTAINING AGERITE DPPD AS REPLACEMENT FOR N.B.C.

Formulation No.	A3a-11	A3a-12	A3a-13
Neoprene 750	80.0	80.0	80.0
Neoprene 571	20.0	20.0	20.0
Zinc Oxide	5.0	5.0	5.0
Neozone 'D'	2.0	2.0	2.0
Agerite DPPD	1.0	2.0	3.0
Accelerator 833	1.0	1.0	1.0
Sunaptic Acid	1.0	1.0	1.0
Aquarex SMO	0.5	0.5	0.5
Dibutyl Sebacate	6.25	6.25	6.25

FACTUAL DATA (CONTINUED)

TASK A PHASE 3 PART A (CONTINUED)

TABLE 85

PHYSICAL PROPERTIES OF COMPOUNDS A3a-11, A3a-12, A3a-13, AND A3-105 TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Streng. (psi)	Elong. at Break (%)	Tear Streng. (lb/in)	Time to Rupture in Ozone (min)
A3a-11	60	240	110	165	335	1415	1115	65	
	90	240	120	190	345	1525	1070	43	
	120	240	125	180	310	1560	1065	63	25
	60	260	115	165	315	1525	1020	62	
	90	260	140	180	355	1550	875	61	
	120	260	145	190	430	1645	830	84	20
	60	280	160	200	360	1885	885	71	
	90	280	150	175	405	2090	870	72	
	120	280	150	195	420	1960	840	70	30
A3a-12	60	240	100	170	320	1325	1050	55	
	90	240	105	175	335	1460	1030	55	
	120	240	140	200	390	1670	910	63	165
	60	260	135	185	395	1345	880	44	
	90	260	145	185	355	1460	860	45	
	120	260	145	200	385	1620	840	61	70
	60	280	145	190	385	1500	840	62	
	90	280	150	200	400	1680	825	67	
	120	280	155	200	445	1750	800	75	100
A3a-13	60	240	115	190	365	1445	1030	61	
	90	240	120	185	355	1560	1045	62	
	120	240	125	185	355	1350	920	62	320
	60	260	115	165	285	1620	1020	57	
	90	260	145	185	365	1550	860	52	
	120	260	155	195	365	1590	835	69	320
	60	280	150	195	345	1700	860	54	
	90	280	150	195	410	1675	820	67	
	120	280	150	195	410	1420	780	61	310
A3-105	60	240	90	155	315	1310	965	58	
	90	240	120	175	310	1630	945	61	
	120	240	125	180	320	1600	900	64	100
	60	260	130	175	315	1400	920	60	
	90	260	135	180	300	1705	920	60	
	120	260	135	190	305	1725	925	70	75
	60	280	120	175	290	1945	925	62	
	90	280	125	165	255	1975	920	65	
	120	280	135	170	285	2000	910	66	95

FACTUAL DATA (continued)

TASK A, Phase 3, Part A (continued)

Accordingly, the number A3-117 was assigned to compound A3a-13. A sufficient quantity of this compound was prepared for balloon manufacture, and plates were dipped according to standard procedure. They were cured for 60, 90, and 120 minutes at 240°F, 260°F, and 280°F, and physical properties were determined at room temperature and at -40°C. The results of these tests are given in Table 86.

A study of these results shows that by curing at 240°F, instead of at 280°F as normally used for compound A3-105, satisfactory elongations at room temperature and at -40°C can be obtained with compound A3-117. Balloons were therefore made from this compound and submitted for flight testing.

* * * * * * *

A compound containing Lytron 615 which produced balloons having very erratic performance was shown to have very poor ozone resistance. Accordingly, a compound was designed containing Agerite DPPD and Wingstay 'T' in an effort to improve this characteristic. This compound was designated A3-112, and plates were dipped and cured and room-temperature physical characteristics had been determined when the deleterious effect of Wingstay 'T' on ozone resistance was discovered.

Therefore, compound A3-115 was designed to eliminate the Wingstay 'T'; and, in addition, a third compound, A3-118, with a larger plasticizer content was also prepared. The formulations of these compounds follow:

	A3-112	A3-115	A3-118
Neoprene 750	80.0	80.0	80.0
Neoprene 571	20.0	20.0	20.0
Lytron 615	15.0	15.0	15.0
Zinc Oxide	5.0	5.0	5.0
Neozone 'D'	-	2.0	2.0
Wingstay 'T'	2.0	-	-
Agerite DPPD	3.0	3.0	3.0
Accelerator 833	1.0	1.0	1.0
Sunaptic Acid	1.0	1.0	1.0
Aquarex SMO	0.5	0.5	0.5
Dibutyl Sebacate	6.25	6.25	16.0

Plates were dipped according to standard procedure and cured for 60, 90, and 120 minutes at 240°F, 260°F, and 280°F. Physical characteristics were determined at room temperature and at -40°C except in the case of A3-112

TABLE 86

PHYSICAL PROPERTIES OF COMPOUND A3-117
TESTED AT ROOM TEMPERATURE AND AT -40°C

Test Temp. (°C)	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
+20	60	240	115	190	365	1445	1030	61
+20	90	240	120	185	355	1560	1045	62
+20	120	240	125	185	355	1350	920	62
+20	60	260	115	165	285	1620	1020	57
+20	90	260	145	185	365	1550	860	52
+20	120	260	155	195	365	1590	835	69
+20	60	280	150	195	345	1700	860	54
+20	90	280	150	195	410	1275	820	67
+20	120	280	150	195	410	1420	780	61
-40	60	240	255	735	2950	3495	630	-
-40	90	240	310	925	3180	3810	640	-
-40	120	240	335	730	2950	3425	620	-
-40	60	260	760	1580	-	3730	590	-
-40	90	260	970	1855	-	4550	580	-
-40	120	260	1060	1940	-	4235	570	-
-40	60	280	1145	1965	-	4840	590	-
-40	90	280	975	1830	-	2070	570	-
-40	120	280	1315	2345	-	4420	550	-

FACTUAL DATA (continued)

TASK A, Phase 3, Part A (continued)

where the low temperature testing was eliminated because of the poor ozone resistance which was no better than that of the earlier compound containing Lytron 615. The results of these tests are given in Tables 87 and 88.

In view of the low elongations shown by compound A3-115 at higher cures, room-temperature testing on compound A3-118 was restricted to the 240°F cures, and all low temperature testing was restricted to the 240°F cures.

A study of these results show that increasing the plasticizer content has, as was anticipated, improved the elongation at -40°C and that both compounds A3-115 and A3-118 have acceptable room-temperature physicals. Balloons were therefore made from both of these compounds and submitted for flight testing.

* * * * * * *

Compounds based solely upon Neoprene 750 generally have too low room-temperature modulus to permit safe launching. Since Agerite DPPD increases modulus, it was felt that incorporation of this material would raise the room-temperatue modulus to a safe level and confer the additional benefit of improved ozone resistance. Accordingly, compound A3-114 was prepared, the formula for which is given below:

	Compound A3-114
Neoprene 750	100.0
Zinc Oxide	5.0
Neozone 'D'	2.0
Agerite DPPD	3.0
Accelerator 833	1.0
Sunaptic Acid	1.0
Aquarex SMO	0.5
Butyl Oleate	10.0

This compound is identical with A3-101 except that it contains Agerite DPPD, and the Dibutyl Sebacate is replaced by Butyl Oleate to improve low temperature characteristics.

Plates were dipped from this compound and from A3-101 for comparisons and cured for 60, 90 and 120 minutes at 240°F, 260°F, and 280°F. Physical properties were determined at room temperature and at -40°C, and the results are recorded in Tables 89 and 90.

TABLE 87

PHYSICAL PROPERTIES OF COMPOUNDS A3-112, A3-115, AND A3-118 TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
A3-112	60	240	160	360	670	1700	960	114
	90	240	165	340	690	1635	975	106
	120	240	165	310	620	1720	1025	116
	60	260	175	335	670	2080	1045	121
	90	260	200	415	850	2085	935	140
	120	260	180	375	660	2115	1000	155
	60	280	175	290	590	2220	1100	135
	90	280	205	370	770	2490	980	152
	120	280	220	450	900	2305	870	152
A3-115	60	240	310	650	1180	2555	915	223
	90	240	310	640	1185	2265	900	192
	120	240	330	625	1185	2480	915	200
	60	260	345	760	1370	2880	870	207
	90	260	380	830	1765	2735	770	181
	120	260	410	875	1840	2825	740	195
	60	280	510	1035	2205	3110	740	188
	90	280	520	1030	2155	3005	730	200
	120	280	565	1300	2655	3115	660	216
A3-118	60	240	155	280	565	1235	900	76
	90	240	170	310	620	1380	895	96
	120	240	170	315	625	1450	885	96
	remaining cures not tested							

FACTUAL DATA (continued)

TASK A, Phase 3, Part A (continued)

TABLE 88

PHYSICAL PROPERTIES OF COMPOUNDS A3-115 AND A3-118
TESTED AT -40°C.

Compound No.	Cure Time (mins)	Cure Temp. (°F.)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A3-115	60	240	1005	2875	-	3380	480
	90	240	1080	3025	-	4495	500
	120	240	1125	3040	-	4510	500
A3-118	60	240	415	1595	-	2915	580
	90	240	475	1745	4050	4265	620
	120	240	550	1905	-	4245	580

TABLE 89

PHYSICAL PROPERTIES OF COMPOUNDS A3-114 AND A3-101
TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
A3-114	60	240	80	130	285	1165	1085	47
	90	240	75	130	245	1550	1075	54
	120	240	85	130	230	1380	1065	58
	60	260	115	145	265	1375	1100	52
	90	260	120	160	275	1660	1000	50
	120	260	120	165	265	1440	920	54
	60	280	105	135	210	1655	1080	54
	90	280	135	160	240	1910	970	56
	120	280	130	160	245	1970	950	67
A3-101	60	240	95	140	200	1275	1150	47
	90	240	110	145	185	1535	1110	58
	120	240	105	145	200	1500	1110	63
	60	260	110	135	190	1480	1030	60
	90	260	105	145	215	1540	965	60
	120	260	110	145	215	1655	960	57
	60	280	120	150	215	1950	1040	68
	90	280	130	170	220	1800	970	69
	120	280	135	155	225	2035	970	70

TABLE 90

PHYSICAL PROPERTIES OF COMPOUNDS A3-114 AND A3-101
TESTED AT -40°C

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A3-101	60	240	115	165	750	2480	770
	90	240	115	170	810	3405	800
	120	240	125	180	825	3125	790
	60	260	125	175	875	3020	770
	90	260	120	115	790	2460	740
	120	260	130	195	1105	3085	750
	60	280	135	210	1070	3075	730
	90	280	125	185	1015	3735	760
	120	280	145	230	1340	3950	740
A3-114	60	240	200	355	1895	2525	640
	90	240	195	330	1910	3160	690
	120	240	190	320	1955	3495	700
	60	260	220	330	2005	2500	630
	90	260	215	385	2495	3495	660
	120	260	245	460	3090	3790	650
	60	280	240	375	2410	3375	660
	90	280	335	700	3485	4325	630
	120	280	370	1005	3860	4865	630

FACTUAL DATA (continued)

TASK A, Phase 3, Part A (continued)

A study of these results shows that compound A3-114 has a higher modulus at room temperature than does A3-101. However, the tests at -40°Cshow that A3-114 has an elongation approximately 100% less than A3-101. The elongation at -40°C is therefore equal to that of A3-105, and the only improvement would be in ozone resistance.

Since A3-117 has similar ozone resistance and about the same elongation at -40°C, it does not appear that A3-114 has any further interest; and no balloons were made from this compound.

Tests conducted on Neoprene 400 showed that extremely high modulus films can be obtained by blending this polymer with Neoprene 750. Neoprene 400 will produce higher modulus than Neoprene 571 and an equally high modulus to that obtained by the use of sulphur.

Neoprene 400, of course, has the advantage over sulphur in that it shows no tendency to settle, and there is no possibility of cross linking occurring in the latex with consequent loss of wet gel extensibility.

Compound A3-130 was, therefore, prepared, the formulation of which is given below:

	Compound A3-130
Neoprene 750	75.0
Neoprene 400	25.0
Zinc Oxide	5.0
Neozone 'D'	2.0
N.B.C.	3.0
Accelerator 833	1.0
Sunaptic Acid	1.0
Aquarex SMO	0.5
Dibutyl Sebacate	6.25

Plates were dipped from this compound using standard procedure and cured for 90, 120 and 150 minutes at 280°F. Cures were conducted at this temperature only since it was previously established that a temperature of 280°F is necessary to develop the high modulus of the Neoprene 400.

Physical properties were determined, and the results are given in Table 91.

A study of these results shows that the compound is very flat curing and indicates that it should produce balloons with good flight characteristics.

TABLE 91

PHYSICAL PROPERTIES OF COMPOUND A3-130
TESTED AT ROOM-TEMPERATURE AND AT -40°C.

Compound No.	Test Temp. (°C.)	Cure Time (mins)	Cure Temp. (°F.)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elong. at Brk. (%)	Tear Strength (lbs/in)
A3-130	+20	90	280	150	205	390	2670	960	86
	+20	120	280	145	205	380	2650	930	80
	+20	150	280	150	210	440	2675	910	84
A3-130	-40	90	280	760	1510	4020	4930	635	-
	-40	120	280	830	1600	3910	4785	640	-
	-40	150	280	810	1740	3825	4880	630	-

FACTUAL DATA (continued)

TASK A, Phase 3, Part A (continued)

Since the bulk of the work is presently being conducted on dual-purpose balloons, it was decided to post-plasticize this compound in order to render it suitable for night flights.

A balloon so treated showed the following physical characteristics:

Test temperature (°C)	+20	-70
Modulus at 200% (psi)	105	620
Modulus at 400% (psi)	170	1245
Modulus at 600% (psi)	375	--
Tensile Strength (psi)	1210	2835
Elongation (%)	780	590
Tear Strength (lbs/in)	67	--

These results suggest that these balloons will perform satisfactorily at night, and the flight results obtained are given in Phase 4.

The use of Merac as an accelerator has already been described in Task A, Phase 2, Part D. Accordingly, a compound containing Merac as a direct substitute for Accelerator 833 was prepared. This compound is designated A3-132, the formulation for which is as follows:

	Compound A3-132
Neoprene 750	80.0
Neoprene 571	20.0
Zinc Oxide	5.0
Neozone 'D'	2.0
N.B.C.	3.0
Merac	1.0
Sunaptic Acid	1.0
Aquarex SMO	0.5
Dibutyl Sebacate	6.25

Balloons were prepared from this compound, and cured for 90 minutes at 260°F which is the optimum cure indicated by the results obtained in the previous study of this accelerator.

During the course of this study it has been observed that the use of certain compounding ingredients, notably, Wingstay 'T' and Accelerator 833 have the property of increasing elongation quite substantially.

FACTUAL DATA (continued)

TASK A, Phase 3, Part A (continued)

A series of dual-purpose compounds was designed and evaluated (see Task A, Phase 3, Part B), and some success was shown, particularly in that the elongation at -70°C was increased although not to the degree that was hoped for. A group of day-flight compounds was next prepared, and the formulations for these are given in Table 92.

Plates were dipped from each of these compounds and cured for 90 minutes at 250°F and 90 minutes at 280°F. Physical properties were determined at room temperature, and the results of these tests, together with the results of room-temperature physical tests performed on uncured films are given in Table 93.

A study of these results shows that the only two compounds which have room-temperature elongations in excess of 1250% are A3-152 and A3-153. However, in both cases the modulus at 600% elongation is undesirably low.

Nevertheless, it was considered worthwhile to pursue this further, particularly in view of the fact that although the modulus is low, the tensile strength is satisfactory, and it should be possible to evaluate the flight performance of balloons made from either of these compounds if care is exercised in handling the balloon on the ground before launching.

An additional compound was prepared in which the Dibutyl Sebacate was increased to 10 parts. This compound was designated A3-154, and its formula is as follows:

	Compound A3-154
Neoprene 750	100.0
Zinc Oxide	5.0
Neozone 'D'	2.0
N.B.C.	3.0
Sunaptic Acid	1.0
Aquarex SMO	0.5
Accelerator 833	3.0
Wingstay 'T'	4.0
Dibutyl Sebacate	10.0

Plates were dipped from this compound according to standard procedure, and these and additional plates from compound A3-153 were cured for 120 minutes at 240°F. Physical properties were determined at room temperature and at -50°C, and the results of these tests are given in Table 94.

FACTUAL DATA (continued)

TASK A, Phase 3, Part A (continued)

TABLE 92

FORMULATIONS OF COMPOUNDS DESIGNED FOR HIGH ELONGATION

Formulation No.	A3-147	A3-148	A3-149	A3-150	A3-151	A3-152	A3-153
Neoprene 750	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Zinc Oxide	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Neozone 'D'	-	2.0	2.0	2.0	2.0	2.0	2.0
N.B.C.	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Sunaptic Acid	-	-	-	1.0	1.0	1.0	1.0
Aquarex SMO	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Accelerator 833	1.0	1.0	1.0	1.0	2.0	3.0	3.0
Wingstay 'T'	-	-	-	-	-	-	4.0
Dibutyl Sebacate	-	-	6.25	6.25	6.25	6.25	6.25

FACTUAL DATA (continued)

TASK A, Phase 3, Part A (continued)

TABLE 93

PHYSICAL PROPERTIES OF COMPOUNDS A3-147 THROUGH A3-153
TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
A3-147	uncured	-	115	190	410	1950	1200	71
	90	250	165	195	250	2500	1210	72
	90	280	195	250	490	4505	1010	162
A3-148	uncured	-	110	165	380	1450	1165	60
	90	250	140	195	400	2880	980	82
	90	280	160	215	450	3360	940	96
A3-149	uncured	-	70	100	220	810	1120	31
	90	250	105	165	225	2260	1080	65
	90	280	130	180	285	2785	1000	77
A3-150	uncured	-	70	100	225	780	1125	31
	90	250	90	155	240	2050	1060	83
	90	280	115	175	280	2500	1000	106
A3-151	uncured	-	60	100	225	780	1120	36
	90	250	135	180	270	2620	1170	88
	90	280	165	200	350	3440	1045	96
A3-152	uncured	-	65	95	185	775	1190	32
	90	250	110	140	190	2300	1270	69
	90	280	130	175	240	3475	1080	94
A3-153	uncured	-	50	75	130	553	1200	21
	90	250	80	105	145	2330	1330	72
	90	280	125	170	260	2980	1080	90

FACTUAL DATA (continued)

TASK A, Phase 3, Part A (continued)

TABLE 94

PHYSICAL PROPERTIES OF COMPOUNDS A3-153 AND A3-154 TESTED AT ROOM-TEMPERATURE AND -50°C.

Compound No.	Test Temp. (°C.)	Cure Time (mins)	Cure Temp. (°F.)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elong. at Burst (%)	Tear Strength (lbs/in)
A3-153	+20	120	240	80	100	160	1700	1310	63
	-50	120	240	925	1220	3010	4890	700	-
A3-154	+20	120	240	70	90	100	1025	1275	41
	-50	120	240	545	920	2060	4020	740	-

FACTUAL DATA (continued)

TASK A, Phase 3, Part A (continued)

A study of these results shows that both compounds have high room temperature elongation in the order of 1300%. The room-temperature modulus is of course, still low and that of A3-154 is lower than that of A3-153 as can be expected in view of the higher plasticizer content.

However, both of these compounds show significantly higher elongation at -50°C than is normally obtained at -40°C with standard balloon compounds. If it is possible to increase the room-temperature modulus at 600% to a figure in the order of 300 psi, without reducing the elongation, then balloons made from such compounds should reach significantly higher altitudes and still offer no problem insofar as handling at launch is concerned.

A series of compounds was therefore designed with a view to obtaining an improvement in room-temperature modulus without loss of elongation. These formulations are given in Table 95.

Plates were dipped from these compounds according to standard procedure and cured for 60 and 90 minutes at 240°F and 260°F. Physical properties were determined at room temperature and at -40°C, and the results of these tests are given in Tables 96 and 97.

A study of these results shows that the objective of increasing room-temperature modulus has satisfactorily been achieved. Compound A3-152 and A3-153 both gave room temperature elongations in the order of 1300%, but the corresponding 600% modulus figures ranged from 145 psi to 190 psi, which is impractically low.

The only compounds in the present series to yield room-temperature elongations in the order of 1300% were A3-155 and A3-156. Elongations in excess of 1470% were recorded on the former compound and of more than 1400% on the latter. The modulus at 600% is, however, much too low and in addition it should be noted that there is a relatively small difference between the modulus at 200% and 600%. This is likely to result in serious distortion of the balloon during flight.

Compound A3-157 has very interesting properties. Although the room temperature elongation is only 1185% at the maximum, this is associated with a 300% modulus of 310 psi, which is quite satisfactory. When tested at -40°C, this same sample showed an excellent elongation of 820%.

TABLE 95

FORMULATIONS OF COMPOUNDS DESIGNED FOR HIGH ELONGATION

Formulation No.	A3-155	A3-156	A3-157	A3-158	A3-159	A3-160	A3-161	A3-162
Neoprene 750	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Zinc Oxide	1.0	5.0	1.0	1.0	1.0	1.0	2.5	1.0
Wingstay 'T'	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
N.B.C.	-	-	3.0	3.0	3.0	3.0	3.0	3.0
Sunaptic Acid	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Aquarex SMO	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Accelerator 833	1.0	3.0	1.0	1.0	1.0	1.0	1.0	-
Merac	-	-	-	-	-	-	-	1.0
Dibutyl Sebacate	5.0	5.0	5.0	5.0	10.0	-	-	-
Butyl Oleate	-	-	-	-	-	10.0	5.0	5.0
Mistron Vapor	-	-	5.0	10.0	10.0	10.0	5.0	-

FACTUAL DATA (continued)

TASK A, Phase 3, Part A (continued)

TABLE 96

PHYSICAL PROPERTIES OF COMPOUNDS A3-155 THROUGH A3-162
TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A3-155	60	240	105	115	155	1620	1375+
	90	240	85	95	110	1525	1470+
	60	260	100	115	130	1970	1475
	90	260	90	110	135	1500	1100
A3-156	60	240	125	145	210	2080	1265
	90	240	105	125	155	1770	1345
	60	260	100	115	135	1725	1415
	90	260	110	130	155	2040	1165
A3-157	60	240	125	175	300	1615	1175
	90	240	175	225	355	2355	975
	60	260	180	200	310	2465	1185
	90	260	155	225	430	3400	1035
	120	260	165	230	470	3755	1045
A3-158	60	240	205	275	495	2350	975
	90	240	205	280	550	2615	910
	60	260	225	315	600	2795	945
	90	260	235	315	635	3005	915
A3-159	60	240	115	180	320	2210	1085
	90	240	155	215	310	2380	1105
	60	260	165	230	340	2415	1185
	90	260	175	215	345	2510	1100
A3-160	60	240	120	155	260	2040	1210
	90	240	135	175	320	2160	1125
	60	260	125	185	335	2255	1205
	90	260	155	225	385	2540	1130
A3-161	60	240	140	205	320	2570	1100
	90	240	125	160	260	2560	1180
	60	260	140	175	275	2355	1155
	90	260	145	210	320	2590	1065
A3-162	60	240	125	180	230	2640	1000
	90	240	105	135	185	2495	1175
	60	260	125	155	210	2410	1075
	90	260	120	155	235	2675	1035

FACTUAL DATA (continued)

TASK A, Phase 3, Part A (continued)

TABLE 97

PHYSICAL PROPERTIES OF COMPOUNDS A3-155 THROUGH A3-162 TESTED AT -40°C

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A3-155	60	240	190	240	1298	1683	640
	90	240	145	200	735	1910	740
	60	260	180	300	1250	2855	720
	90	260	215	265	1255	3140	740
A3-156	60	240	180	315	1000	1625	680
	90	240	190	255	640	1795	760
	60	260	205	340	1755	2635	700
	90	260	260	450	-	1605	580
A3-157	60	240	180	415	1600	3690	780
	90	240	255	515	2630	3655	680
	60	260	120	245	610	2865	820
	90	260	385	1155	3845	6155	700
	120	260	385	1220	3275	4810	680
A3-158	60	240	390	780	2815	4065	680
	90	240	355	930	-	3070	580
	60	260	460	985	3225	3485	640
	90	260	545	1795	3595	3985	620
A3-159	60	240	180	475	1250	2675	780
	90	240	190	385	1345	1345	600
	60	260	355	930	2785	2785	600
	90	260	350	700	2265	2850	660
A3-160	60	240	160	435	1430	1510	600
	90	240	165	540	1460	1960	660
	60	260	220	660	1655	1910	640
	90	260	280	675	-	1745	580
A3-161	60	240	260	675	-	1770	580
	90	240	230	510	-	1530	560
	60	260	330	755	-	1935	540
	90	260	295	635	-	1910	560
A3-162	60	240	165	270	1415	1630	640
	90	240	135	235	1165	1565	660
	60	260	155	270	-	1075	580
	90	260	170	300	1680	1895	600

TASK A, Phase 3, Part A (continued)

It would appear, therefore, that balloons made from compound A3-157 should reach higher altitudes than balloons of the same weight and length made from compound A3-105.

Compound A3-158 also shows interesting properties. The elongation at room temperature is substantially lower than any of the other compounds in this series. However, the elongation at -40°C is over 600%, and this is coupled with a room-temperature modulus of more than 600 psi, indicating that this compound shows excellent promise for fast-rising balloons.

The remaining compounds all show relatively high room-temperature elongation and acceptable room-temperature modulus. The elongations at -40°C are also satisfactory, but are inferior to that exhibited by compound A3-157.

Part B: Dual-Purpose Balloon Compounds

The results obtained in Task A, Phase 2, Part B indicated that better low-temperature characteristics can be realized by using a blend of Dibutyl Sebacate and Butyl Oleate than with either of the two plasticizers alone. Accordingly, a sufficient quantity of compound A2b-5 was prepared for balloon manufacture, this compound now being designated as A3-104. The formula and physical properties of this compound have been reported in Phase 2, Part B (see Tables 25 thru 28) and are not repeated here. Balloons were made from this compound, and the flight results are given in Task A, Phase 4, Part B.

In addition, balloons were made from compound A3-103, the formulation for which is as follows:

	Compound A3-103
Neoprene	100.0
Zinc Oxide	1.0
Neozone 'D'	2.0
N.B.C.	3.0
Accelerator 833	1.0
Sunaptic Acid	1.0
Aquarex SMO	0.5
Butyl Oleate	25.0
Sulphur	3.0

FACTUAL DATA (continued)

TASK A, Phase 3 (continued)

Plates were dipped from this compound according to standard procedure, and physical properties were determined at room temperature and at -70°C. The results of these tests are given in Table 98.

A study of these results shows that this compound when cured for either 80 minutes at 240°F or 40 minutes at 260°F has satisfactory properties for a dual-purpose balloon. Accordingly, balloons were made from this compound and submitted for flight testing.

Incorporation of sufficient plasticizer into a balloon compound to render it capable of performance at night results in very soft, low-modulus compounds with poor ozone resistance. In the past, the modulus of the compound has been raised by incorporating sulphur. It would now appear that this can be achieved by use of Neoprene 400.

Furthermore, this will improve the ozone resistance, and the use of Agerite DPPD will improve it still further. Wingstay 'T' will help to maintain a high elongation which will have been reduced by incorporation of Neoprene 400 and Agerite DPPD.

Two compounds were designed, the formulations of which are given below:

	A3-110	A3-111
Neoprene 750	60.0	50.0
Neoprene 400	40.0	50.0
Zinc Oxide	5.0	5.0
Wingstay 'T'	2.0	3.0
Agerite DPPD	3.0	3.0
Accelerator 833	1.0	1.0
Sunaptic Acid	1.0	1.0
Aquarex SMO	0.5	0.5
Butyl Oleate	25.0	25.0

TABLE 98

PHYSICAL PROPERTIES OF BALLOON FILMS MADE FROM COMPOUND A3-103 TESTED AT ROOM TEMPERATURE AND AT -70°C

Test Temp. (°C)	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
+20	40	240	75	200	470	890	860	37
+20	60	240	70	170	415	1060	930	36
+20	80	240	75	180	420	1080	935	39
+20	40	260	85	205	490	1055	895	33
+20	60	260	80	175	415	1125	955	60
+20	80	260	80	155	345	1385	1020	62
+20	40	280	70	180	425	935	865	48
+20	60	280	90	165	350	1610	1045	35
+20	80	280	80	145	330	1505	1015	59
-70	40	240	2565	3855	-	4310	430	cold flow
-70	60	240	2630	3485	-	4080	450	cold flow
-70	80	240	2095	3550	-	4265	470	
-70	40	260	2105	3330	-	4420	470	
-70	60	260	-	-	-	3145	0	frozen
-70	80	260	-	-	-	2875	50	frozen
-70	40	280	2115	3365	-	4205	470	
-70	60	280	-	-	-	3995	0	frozen
-70	80	280	-	-	-	3250	0	frozen

FACTUAL DATA (continued)

TASK A, Phase 3, Part B (continued)

However, in view of the effect of Wingstay 'T' on ozone resistance which was subsequently observed, it was decided to hold these compounds in abeyance and design an additional pair which contained less Neoprene 400 and from which the Wingstay 'T' was eliminated. These were designated A3-119 and A3-120, and their formulations are as follows:

	A3-119	A3-120
Neoprene 750	70.0	60.0
Neoprene 400	30.0	40.0
Zinc Oxide	5.0	5.0
Neozone 'D'	2.0	2.0
Agerite DPPD	3.0	3.0
Accelerator 833	1.0	1.0
Sunaptic Acid	1.0	1.0
Aquarex SMO	0.5	0.5
Butyl Oleate	25.0	25.0

Plates were dipped according to standard procedure and cured for 60, 90 and 120 minutes at 240°F, 260°F and 280°F. Physical properties were determined at room temperature and at -70°C, and the results of these tests are given in Tables 99 and 100.

A study of these results shows that both compounds should yield balloons capable of flying by day or by night. The somewhat higher low-temperature elongation of A3-119 indicates that this compound is preferable, and the results also suggest that a reduction in the amount of Neoprene 400 or an increase in the amount of Butyl Oleate might be advantageous.

Compound A3-106, as shown in the previous quarterly report, did not produce a satisfactory 120,000 foot balloon. Nevertheless, according to laboratory tests, compound A3-106 has satisfactory low-temperature characteristics showing no sign of freezing at -70°C, and also having suitable room-temperature characteristics of modulus and tensile strength.

It would appear therefore, that the physical characteristics at room temperature and-70°C which have been established as necessary to ensure performance at the 100,000 foot level are not in themselves, sufficient to provide consistent performance at the 120,000-foot level. The frequency with which balloons do reach a 120,000-foot altitude indicates, however, that only minor modifications in compound or in the balloon itself are required.

TABLE 99

PHYSICAL PROPERTIES OF COMPOUNDS A3-119 AND A3-120
TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
A3-119	60	240	85	165	340	810	835	42
	90	240	95	165	335	895	850	48
	120	240	105	175	355	845	825	40
	60	260	105	170	415	1250	880	45
	90	260	115	195	435	1330	865	55
	120	260	110	180	445	1255	850	47
	60	280	125	195	455	1330	870	54
	90	280	130	215	510	1540	860	71
	120	280	130	230	630	1530	845	65
A3-120	60	240	125	210	430	830	770	39
	90	240	135	225	455	930	800	47
	120	240	135	225	480	965	785	57
	60	260	130	210	475	1270	850	50
	90	260	125	215	465	1175	860	58
	120	260	120	220	500	1175	850	56
	60	280	140	250	540	1370	865	62
	90	280	160	270	660	1740	865	70
	120	280	160	260	655	1540	865	86

TABLE 100

PHYSICAL PROPERTIES OF COMPOUNDS A3-119 AND A3-120
TESTED AT -70°C

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A3-119	60	240	1935	3395	-	3930	440
	90	240	1825	3440	-	4480	480
	120	240	1890	3490	-	4420	450
	60	260	2130	4135	-	5225	490
	90	260	2195	4090	-	4975	470
	120	260	2095	4010	-	4880	450
	60	280	1900	3855	-	4695	480
	90	280	2680	4820	-	5095	420*
	120	280	2980	-	-	4710	360*
A3-120	60	240	2160	4145	-	4420	410
	90	240	2140	4085	-	4675	450
	120	240	2060	4010	-	4535	450
	60	260	2215	4070	-	4615	460
	90	260	2360	4405	-	4860	420
	120	260	2015	4025	-	4625	450
	60	280	2705	4900	-	4900	400
	90	280	2975	-	-	4775	390**
	120	280	2815	4595	-	5230	420**

FACTUAL DATA (continued)

TASK A, Phase 3, Part B (continued)

There appear to be only three major possibilities. The compound should have even better low-temperature characteristics or it should have improved ozone resistance. Thirdly, because of the increased weight of the balloon, the film itself should be somewhat thicker to enable it to support the additional weight of the lower half of the balloon. This latter theory was evaluated theoretically, and the results of this study are given in Task B, Phase 6, Part D.

In order to evaluate the possibilities of greater freeze resistance or greater ozone resistance being the necessary requirement for a satisfactory 120,000-foot balloon, a series of compounds was designed, all of which were modifications of A3-106.

Because all the changes made would result in clearly anticipated alterations in physical properties and because the degree of improvement in low temperature characteristics desired was not known, it was not considered advisable to conduct the considerable amount of laboratory testing that standard procedure would normally require. It was rather considered advisable to perform flight tests in order to determine which compound would perform reliably and then determine the physical characteristics of that compound in order to establish the necessary standards.

This principle was also applied to improving the ozone resistance. Previous laboratory tests (see Final Report of Contract DA-36-039-SC-78239) had shown that by increasing the N.3.C. from three parts to ten parts resulted in a very substantial improvement in ozone resistance. Two compounds were, therefore, designed with five parts and ten parts of N.B.C., respectively.

The formulations of all the compounds designed for this study are given in Table 101. Balloons designed to reach altitudes of at least 120,000 feet were made from each of these compounds, and the results of the flight tests are given in Task A, Phase 4.

TABLE 101

FORMULATIONS OF COMPOUNDS DESIGNED TO PRODUCE 120,000-FOOT, DUAL-PURPOSE BALLOONS

Formulation No.	A3-121	A3-122	A3-123	A3-124	A3-125	A3-126	A3-127
Neoprene 750	80.0	80.0	80.0	80.0	80.0	80.0	80.0
Neoprene 571	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Zinc Oxide	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Neozone "D"	2.0	2.0	2.0	2.0	2.0	2.0	2.0
N.B.C.	3.0	3.0	3.0	3.0	5.0	5.0	10.0
Accelerator 833	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Sunaptic Acid	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Aquarex SMO	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Dibutyl Sebacate	6.25	6.25	6.25	6.25	6.25	6.25	6.25
Butyl Oleate	27.5	-	6.0	6.0	6.0	6.0	6.0
Paraflux C-325	-	27.5	22.5	17.5	17.5	22.5	22.5

FACTUAL DATA (continued)

TASK A, Phase 3, Part B (continued)

Two further compounds were designed to test the flight performance of B.T.N. as an antiozonant and Butoxy Ethyl Oleate as a plasticizer.

The formulations of these compounds are as follows:

	A3-128	A3-129
Neoprene 750	80.0	80.0
Neoprene 571	20.0	20.0
Zinc Oxide	5.0	5.0
Neozone 'D'	2.0	2.0
N.B.C.	--	3.0
B.T.N.	3.0	--
Accelerator 833	1.0	1.0
Sunaptic Acid	1.0	1.0
Aquarex SMO	0.5	0.5
Dibutyl Sebacate	6.25	6.25
Paraflux C-325	22.5	--
Butoxy Ethyl Oleate	--	22.5

Balloons were made from these two compounds, and physical characteristics were determined on the balloons. Results of these tests are as follows:

	Balloon from A3-128	
Test temperature (°C)	+20	-70
Modulus at 200% (psi)	120	160
Modulus at 400% (psi)	190	1910
Modulus at 600% (psi)	310	--
Tensile Strength (psi)	1220	4425
Elongation (%)	810	530
Tear Strength (lbs/in)	49	--

	Balloon from A3-129	
Test Temperature (°C)	+20	-70
Modulus at 200% (psi)	130	700
Modulus at 400% (psi)	205	2035
Modulus at 600% (psi)	405	--
Tensile Strength(psi)	1170	4175
Elongation (%)	760	540
Tear Strength (lbs/in)	46	--

The range of cures already conducted on compounds similar to A3-128 and A3-129 preclude the necessity for repeating a range of cures on the balloons themselves in order to determine the optimum cure since this has already been established.

FACTUAL DATA (continued)

TASK A, Phase 3, Part B (continued)

Flights were performed with balloons made from these compounds, and the results are given in Task A, Phase 4, of this report.

The compound containing Neoprene 400 which was developed in Part A of this phase (A3-130) is not a dual-purpose compound and is only rendered suitable for night flight by post plasticizing. It was therefore, considered desirable to develop a true dual-purpose compound which would take advantage of the high modulus characteristics of Neoprene 400.

Accordingly, compound A3-131 was developed, the formulation for which follows:

	Compound A3-131
Neoprene 750	60.0
Neoprene 400	40.0
Zinc Oxide	5.0
Neozone 'D'	2.0
N.B.C.	3.0
Accelerator 833	1.0
Sunaptic Acid	1.0
Aquarex SMO	0.5
Dibutyl Sebacate	30.0

Although previous studies have shown that Butyl Oleate is a preferable low-temperature plasticizer to Dibutyl Sebacate, it was found necessary to use Dibutyl Sebacate in this compound owing to the apparent incompatibility of Butyl Oleate with Neoprene 400, although this may be due to the fact that the standard Butyl Oleate emulsion is unsatisfactory. It is planned to continue laboratory investigations in order to correct this situation.

Due to the softness of the gel it was impossible to make balloons from this compound and it was abandoned. It was however, found possible to use Dibutyl Sebacate as the only plasticizer in a compound containing Sulphur and Neoprene 571. The formulation for this compound and its optimum physical properties are given below:

FACTUAL DATA (continued)

TASK A, Phase 3, Part B (continued)

	Compound A3-133
Neoprene 750	80.0
Neoprene 571	10.0
Neoprene 735	10.0
Zinc Oxide	5.0
Neozone 'D'	2.0
N.B.C.	3.0
Accelerator 833	1.0
Sunaptic Acid	1.0
Aquarex SMO	0.5
Sulphur	5.0
Dibutyl Sebacate	25.0

	Balloons from A3-133	
Test temperature (°C)	+20	-70
Modulus at 200% (psi)	110	F
Modulus at 400% (psi)	245	R
Modulus at 600% (psi)	470	O
Tensile Strength(psi)	1365	Z
Elongation (%)	825	E
Tear Strength (lbs/in)	42	N

These results confirm the necessity for using Butyl Oleate, Paraflux C-325, or Butoxy Ethyl Oleate as a low-temperature plasticizer. Nevertheless, it was decided to fly balloons made from this compound, and the results of these flights are given in Task A, Phase 4, Part B of this report.

In view of the promising results shown during the evaluation of Merac, three compounds were designed. One of them is a day flight compound (A3-132) and the other two (A3-135 and A3-136) are dual-purpose compounds. The formulations for these compounds are as follows:

	A3-132	A3-135	A3-136
Neoprene 750	80.0	80.0	80.0
Neoprene 571	20.0	20.0	20.0
Zinc Oxide	5.0	5.0	5.0
Neozone 'D'	2.0	2.0	2.0
N.B.C.	3.0	3.0	3.0
Accelerator 833	--	0.5	--
Merac	1.0	0.5	1.0
Sunaptic Acid	1.0	1.0	1.0
Aquarex SMO	0.5	0.5	0.5
Dibutyl Sebacate	6.25	6.25	6.25
Paraflux C-325	--	22.5	22.5

FACTUAL DATA (continued)

TASK A, Phase 3, Part B (continued)

The purpose of compound A3-135 was to determine the effect of using a blend of two accelerators, such conditions not having been previously studied in this research. Since the optimum cure has already been established for compounds containing Merac, the physical properties of these compounds were determined at that cure only. The results follow:

	Balloon from A3-132	
Test temperature (°C)	+20	-40
Modulus at 200% (psi)	140	405
Modulus at 400% (psi)	200	1165
Modulus at 600% (psi)	365	3100
Tensile Strength(psi)	2150	4275
Elongation (%)	980	710
Tear Strength (lbs/in)	73	--

	Balloon from A3-135	
Test temperature (±C)	+20	-70
Modulus at 200% (psi)	115	1170
Modulus at 400% (psi)	195	3000
Modulus at 600% (psi)	415	--
Tensile Strength (psi)	1340	4410
Elongation (%)	800	545
Tear Strength (lbs/in)	47	--

	Balloon from A3-136	
Test temperature (°C)	+20	-70
Modulus at 200% (psi)	105	1040
Modulus at 400% (psi)	180	2970
Modulus at 600% (psi)	355	--
Tensile Strength (psi)	1460	5210
Elongation (%)	820	530
Tear Strength (lbs/in)	52	--

It is clear from these results that balloons made from compounds A3-135 and A3-136 should be satisfactory at the 100,000-foot level but cannot be expected to be superior to balloons made from A3-106. The higher modulus indicates a satisfactory rate of ascent.

Day-flight balloons made from compound A3-132 should be equal, if not slightly superior, to those made from compound A3-105. Balloons were, therefore, submitted for flight testing, and the results of the flights are given in Task A, Phase 4, Part B of this report.

FACTUAL DATA (continued)

TASK A, Phase 3, Part B (continued)

Results obtained with Mistron Vapor (see Task A, Phase 2, Part F) suggest that improved rates of ascent might be obtained in dual-purpose compounds which contain this material because of the higher modulus it yields. At the same time, there should be no loss in altitudes since the elongation is relatively unaffected. Accordingly, compound A3-137 was designed, the formulation and physical properties of which follow:

	Compound A3-137
Neoprene 750	80.0
Neoprene 571	20.0
Mistron Vapor	10.0
Zinc Oxide	5.0
Neozone 'D'	2.0
N.B.C.	3.0
Accelerator 333	1.0
Sunaptic Acid	1.0
Aquarex SMO	0.5
Dibutyl Sebacate	6.25
Paraflux C-325	22.5

	Balloon from A3-137	
Test temperature (°C)	+20	-70
Modulus at 200% (psi)	130	1320
Modulus at 400% (psi)	190	3690
Modulus at 600% (psi)	425	--
Tensile Strength (psi)	1500	5280
Elongation (%)	810	520
Tear Strength (lbs/in)	55	--

As anticipated, the room-temperature modulus is substantially higher than that of compound A3-106 yet the elongation at both room temperature and at -70°C is not reduced. Accordingly, balloons were made from this compound, and their flight performance is recorded in Task A, Phase 4, Part B of this report.

One of the objectives throughout this study has been to increase the elongation at -70°C of dual-purpose compounds. Several compounds have been developed which do not freeze at this temperature, but in each case the elongation has been in the order of 500%. These compounds have performed satisfactorily when balloons were made from them and have generally resulted in similar bursting altitudes for a given size balloon.

FACTUAL DATA (continued)

TASK A, Phase 3, Part B (continued)

The way to substantially increase the bursting altitude of a given size balloon is by improving the low-temperature elongation of the film. Increasing the amount of Accelerator 833 was effective for day-flight balloon compounds, but was not so for dual-purpose compounds. (See Task A, Phase 2, Part D). However, Wingstay 'T' provides a means of achieving improved elongation at -40°C in a day-flight compound and may possibly result in a similar increase in dual-purpose compounds.

Accordingly, a series of nine compounds, identified as A3-138 through A3-146 was designed. The formulations of these compounds are given in Table 102, a study of which shows that the changes are restricted to the six materials: Neozone 'D', N.B.C., Accelerator 833, Merac, Wingstay 'T' and B.T.N.

Plates were dipped from these compounds according to standard procedure and cured for 60, 90 and 120 minutes at 250°F. Physical properties were determined at room temperature and at -70°C, and the results of these tests are given in Tables 103 and 104.

A study of these tables shows some extremely interesting results. All compounds tested showed satisfactory room-temperature tensile strength and elongation.

Compounds A3-140, A3-141 and A3-145, in particular, show unusually high elongations for dual-purpose compounds; and the tear strength of A3-141 and A3-145 is, in general, above average.

At -70°C almost every compound shows substantially higher elongation than has hitherto been obtainable. In particular, compounds A3-142 and A3-145 both reach elongations of 600%, the latter compound having an elongation of 600% or better at all cures tested.

FACTUAL DATA (continued)

TASK A, Phase 3, Part B (continued)

TABLE 102

FORMULATIONS OF DUAL-PURPOSE BALLOON COMPOUNDS

Formulation No.	A3-138	A3-139	A3-140	A3-141	A3-142	A3-143	A3-144	A3-145	A3-146
Neoprene 750	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0
Neoprene 571	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Neoprene 735	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Zinc Oxide	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Neozone 'D'	1.0	1.0	-	-	1.0	1.0	1.0	-	1.0
N.B.C.	3.0	3.0	3.0	3.0	3.0	-	-	-	3.0
Sunaptic Acid	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Aquarex SMO	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Dibutyl Sebacate	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Butyl Oleate	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
Sulphur	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Accelerator 833	1.0	-	-	1.0	1.0	1.0	-	-	0.5
Merac	-	1.0	1.0	-	-	-	1.0	1.0	0.5
Wingstay 'T'	-	-	2.0	2.0	2.0	-	-	2.0	-
B.T.N.	-	-	-	-	-	3.0	3.0	3.0	-

FACTUAL DATA (continued)

TASK A, Phase 3, Part B (continued)

TABLE 103

PHYSICAL PROPERTIES OF DUAL-PURPOSE BALLOON COMPOUNDS A3-138 THROUGH A3-146 TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
A3-138	60	250	95	140	290	1405	830	35
	90	250	100	155	300	1450	830	35
	120	250	95	150	295	1430	810	40
A3-139	60	250	95	145	280	1370	815	40
	90	250	100	150	280	1470	820	40
	120	250	100	150	275	1440	815	35
A3-140	60	250	90	125	200	1315	930	35
	90	250	100	135	245	1335	850	40
	120	250	105	145	245	1400	845	40
A3-141	60	250	95	135	200	1470	940	40
	90	250	95	140	220	1375	885	45
	120	250	105	155	275	1630	870	50
A3-142	60	250	100	145	235	1455	875	45
	90	250	105	150	245	1435	865	45
	120	250	115	165	330	1460	815	45
A3-143	60	250	105	145	235	1310	865	40
	90	250	105	150	270	1375	840	40
	120	250	105	155	315	1540	830	40
A3-144	60	250	90	145	245	1400	865	50
	90	250	100	145	255	1470	850	45
	120	250	100	155	305	1545	840	45
A3-145	60	250	85	120	185	1225	960	40
	90	250	100	140	220	1530	920	40
	120	250	105	155	245	1535	880	51
A3-146	60	250	105	155	260	1630	875	45
	90	250	110	170	295	1660	835	45
	120	250	110	180	305	1650	830	45

TABLE 104

PHYSICAL PROPERTIES OF DUAL-PURPOSE BALLOON COMPOUNDS A3-138 THROUGH A3-146 TESTED AT -70°C

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A3-138	60	250	1090	2235	-	3380	520
	90	250	1275	2830	-	4235	500
	120	250	1680	3040	-	3840	480
A3-139	60	250	1180	1860	-	2720	500
	90	250	1370	2470	-	4230	530
	120	250	1550	3000	-	4635	530
A3-140	60	250	970	1990	-	3570	540
	90	250	1100	2160	-	4475	570
	120	250	1570	2555	-	4180	530
A3-141	60	250	930	1855	-	3370	570
	90	250	1035	1400	-	3650	580
	120	250	1300	1975	-	3645	550
A3-142	60	250	1005	1815	3870	3915	610
	90	250	1024	1800	-	4055	590
	120	250	1460	2190	-	4245	590
A3-143	60	250	1110	2330	-	4370	560
	90	250	1080	2060	-	3680	560
	120	250	1040	2330	-	4025	550
A3-144	60	250	880	1725	-	3615	580
	90	250	1115	2130	-	3930	560
	120	250	1375	2450	-	4330	570
A3-145	60	250	1055	2020	4675	4675	600
	90	250	1100	2150	4725	4815	610
	120	250	1145	2200	4915	4915	600
A3-146	60	250	910	2065	-	4830	580
	90	250	1050	1960	-	4700	570
	120	250	1275	2110	-	4885	560

FACTUAL DATA (continued)

TASK A, Phase 3, Part B (continued)

There is relatively little difference between these compounds in low-temperature modulus both at 200% and 400%, hence, as a natural consequence, those compounds showing the highest elongations tend to show the highest tensile strength at -70°C.

Both compounds A3-142 and A3-145 are compounds which contain Wingstay 'T', and the ability of this material to increase low-temperature elongation, and to some extent, room-temperature elongation is again demonstrated.

Balloons from these compounds can be expected to reach substantially higher altitudes (an increase of approximately 10,000 feet) than the similar balloons made from compounds having only 500% elongation at the same temperature.

Part C: Fast-Rise Balloon Compounds

Mistron Vapor's ability to raise modulus without reducing elongation suggests that it would produce an excellent high-modulus, fast-rise balloon compound. Accordingly, a day-flight compound (A3-134) was designed, and its formulation and physical properties are given below:

	Compound A3-134
Neoprene 750	80.0
Neoprene 571	20.0
Mistron Vapor	10.0
Zinc Oxide	5.0
Neozone 'D'	2.0
N.B.C.	3.0
Accelerator 833	1.0
Sunaptic Acid	1.0
Aquarex SMO	0.5
Dibutyl Sebacate	6.25

	Balloon from A3-134	
Test temperature (°C)	+20	-40
Modulus at 200% (psi)	260	680
Modulus at 400% (psi)	415	2100
Modulus at 600% (psi)	920	5300
Tensile Strength(psi)	2915	5525
Elongation (%)	890	620
Tear Strength (lbs/in)	115	--

FACTUAL DATA (continued)

TASK A, Phase 3, Part C (continued)

These results are as anticipated, and the modulus of this compound is greater than that of the sulphur-bearing, fast-rise compound A3-102. Balloons were therefore made from this compound for use in the construction of two-piece, streamlined balloons; the flight results of which are given in Task C, Phase 3.

In addition, balloons were post-plasticized for night flight, and the following physical properties were obtained on such a balloon film:

	Balloon from A3-134 Post-Plasticized		
Test temperature (°C)	+20	-40	-70
Modulus at 200% (psi)	150	760	1290
Modulus at 400% (psi)	240	1840	3020
Modulus at 600% (psi)	560	3960	--
Tensile Strength (psi)	1630	3960	4470
Elongation (%)	810	600	510
Tear Strength (lbs/in)	61	--	--

These results also indicate that good fast-rise balloons could be obtained, the room-temperature modulus still being very high. The fact that the film does not freeze at -70°C indicates that it will fly satisfactorily at night. Therefore, further balloons made from A3-134 were post-plasticized and used in the construction of fast-rise, night-flight balloons. The results of these flights are also recorded in Task C, Phase 3.

Phase 4: Correlation of Film Properties with Flight Data

Part A: High-Altitude Balloons

The emphasis in performance of this contract is on balloons capable of reaching altitudes in excess of 120,000 feet. This is particularly so in the case of day-flight balloons; therefore, most of the balloons submitted for flight have been substantially heavier than the standard balloon of previous contracts which weighed approximately 800 grams.

FACTUAL DATA (continued)

TASK A, Phase 4, Part A (continued)

Eight balloons weighing in the order of 2750 grams prepared from a compound containing 10 parts of plasticizer which was developed during the period between the expiration of Contract DA-36-039-SC-78239 and the beginning of Contract DA-36-039-SC-84925, were submitted for flight testing. These balloons were identified as EX-1 through EX-8 and were flown with a free lift of 1600 grams during the hours of daylight. The results of these flights are given in Table 105.

A study of these results shows that six of the eight balloons (75%) reached altitudes in excess of 120,000 feet, and seven of the eight (87-1/2%) reached altitudes in excess of 110,000 feet. Six of the eight balloons achieved ascensional rates of over 1000 feet per minute.

In view of this satisfactory performance, it was considered worthwhile to make balloons weighing in the order of 1500 grams from this same compound and to determine their performance level. Three balloons were manufactured and submitted for flight testing. These were identified as EX-3A-1001, EX-3A-1002, and EX-3A-1003. They were flown with a free lift of 1600 grams, and the results are recorded in Table 106.

Although one balloon reached an altitude of 128,707 feet, the performance of the remaining two is disappointing. It seems unlikely that the compound possesses insufficient freeze resistance since the performance of the larger balloon is satisfactory.

Four flights were next performed with balloons manufactured from compound A3-105, and these were of a confirmatory nature. Two balloons weighed approximately 750 grams and were about 90 inches long, two weighed 850 grams and were about 100 inches long. The characteristics of these balloons and their flight performances are given in Table 107.

Analysis of these flights immediately indicates that this compound is still equaling its original performance and may be considered as producing a very reliable 90,000-foot (750 grams) or 100,000-foot (850 grams) balloon.

A group of balloons made from compound A3-105 in the 2500 gram class were submitted for flight testing. These balloons were identified as EX-3A-2021 through EX-3A-2026. They were flown with a free lift of 1600 grams, and their characteristics and flight performance are recorded in Table 108.

FACTUAL DATA (continued)

TASK A, Phase 4, Part A (continued)

TABLE 105

FLIGHT RESULTS - BALLOONS MADE FROM COMPOUND CONTAINING 10 PARTS DIBUTYL SEBACATE

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Flaccid Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-1	B16-1	Day	2950	190	128,478	965
EX-2	B17-1	Day	2800	184	108,990	1025
EX-3	B17-3	Day	2725	180	145,833	1106
EX-4	B19-3	Day	2700	178	141,798	1082
EX-5	B19-4	Day	2775	184	112,205	946
EX-6	B19-5	Day	2725	180	127,198	1003
EX-7	B 9-2	Day	2800	188	146,063	1107
EX-8	B 9-3	Day	2775	190	124,311	1015

TABLE 106

FLIGHT RESULTS - BALLOONS MADE FROM COMPOUND CONTAINING 10 PARTS DIBUTYL SEBACATE

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Flaccid Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-1001	H16-5	Day	1625	128	70,000	990
EX-3A-1002	H17-4	Day	1575	133	102,493	1010
EX-3A-1003	H17-6	Day	1650	138	128,707	1091

FACTUAL DATA (continued)

TASK A. Phase 4. Part A (continued)

TABLE 107

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-105

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-205	R31-11T	Day	725	88	95,750	1041
EX-3A-206	R31-12T	Day	750	88	101,000	1005
EX-3A-221	S21-2T	Day	860	101	111,778	1075
EX-3A-222	S21-3T	Day	850	97	107,000	1132

TABLE 108

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-105

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-2021	H2-1AM	Day	2530	178	126,325	1084
EX-3A-2022	H2-4AM	Day	2590	176	123,196	1084
EX-3A-2023	H3-1AM	Day	2575	178	134,383	1007
EX-3A-2024	H3-3AM	Day	2520	177	131,132	1100
EX-3A-2025	H3-4AM	Day	2565	176	130,151	1105
EX-3A-2026	H3-5AM	Day	2535	176	133,399	1115

FACTUAL DATA (continued)

TASK A, Phase 4, Part A (continued)

A study of these results shows that compound A3-105 is extremely satisfactory as a compound for the manufacture of 2500 gram balloons. Sixty-six percent of the flights reached altitudes in excess of 130,000 feet, and all flights were over 120,000 feet. The average of the six flights is approximately 130,000 feet, and the rate of ascent is in every case more than 1000 feet per minute.

Two balloons in the 600-gram class also made from compound A3-105 were, therefore, submitted for flight testing. These balloons were identified as EX-3A-2511 and EX-3A-2512, and were flown with a free lift of 2000 grams. Their physical characteristics and flight performance are given in Table 109.

The flight of balloon EX-3A-2511 is extremely satisfactory, coming very close to the altitude record for a day-flight balloon. The flight of EX-3A-2512, however, suggests that the compound is deficient in low-temperature elongation.

The balloon is not freezing, for if it were the rupture would occur at the tropopause and not at 100,000 feet. It appears, therefore, that additional plasticizer is not necessary for this compound to perform at the 140,000 to 150,000-foot level.

The substantially smaller 2500-gram balloon is already extended at the tropopause, and therefore is less likely to show cold flow as the temperature drops. The 6000-gram balloon, however, is barely rounded out at the tropopause.

In an effort to correct the erratic performance of the 6000-gram balloons, six additional balloons in this weight class were submitted for test. These balloons were identified as EX-3A-2513, EX-3A-2514, EX-3A-2521, EX-3A-2522, EX-3A-2523 and EX-3A-2524. Two of these balloons, EX-3A-2522 and EX-3A-2523, were inserted inside an 800-gram balloon made from the same compound and the remaining four had an 800-gram balloon inserted in the 6000-gram balloon. At inflation the gas was, in all cases, introduced into the inner balloon and the necks of the two balloons were secured to each other. It was felt that by this means the 6000-gram balloon could be induced to expand more uniformly, and localized extension at relatively low altitudes could be avoided. This should eliminate the possibility of parts of the film becoming extremely stiff before it starts to stretch, and hence prevent a situation developing which permits only parts of the film to expand at all.

These balloons were all flown with a free lift of 2000 grams, and their physical characteristics and flight performance are given in Table 110.

FACTUAL DATA (continued)

TASK A, Phase 4, Part A (continued)

TABLE 109

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-105

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-2511	K14-1AM	Day	7075	289	143,701	1099
EX-3A-2512	K22-1AM	Day	7110	312	101,500	953

TABLE 110

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-105

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-2513	R31-1AM	Day	6850	246	128,362	1237
EX-3A-2514	R31-2AM	Day	6570	246	108,793	1031
EX-3A-2521	M12-1AM	Day	8610	325	71,800	1167
EX-3A-2522	M12-2AM	Day	7035	265	136,900	1272
EX-3A-2523	36-1AM	Day	8210	266	133,891	1260
EX-3A-2524	36-2AM	Day	8340	264	73,700	1271

FACTUAL DATA (continued)

TASK A, Phase 4, Part A (continued)

The results obtained are still erratic, only three of the balloons approaching a satisfactory bursting altitude. In at least two of the flights, EX-3A-2521 and EX-3A-2524, it appears that the large balloon broke at the same time as the 800-gram balloon.

A further three balloons were made from compound A3-105, and submitted for flight testing. These balloons, identified as EX-3A-1201 through EX-3A-1203, weighed approximately 1600 grams and were designed to reach an altitude of 120,000 feet. The characteristics of these balloons which were flown with a free lift of 1600 grams, and their flight performance are given in Table 111.

Analysis of these flights confirms the consistent performance of balloons made from compound A3-105. Much data has been accumulated using balloons designed to reach altitudes of 100,000 feet made from this compound, and these balloons have shown excellent consistency. It would also appear that similar consistency may be expected at the 120,000-foot level.

Five balloons made from compound A3-115 which contains Lytron 615 were flown. Previously, balloons made from a similar compound had flown very erratically, and this compound had very poor ozone resistance. Compound A3-115 was designed to improve this property.

These balloons were identified as EX-3A-501 through EX-3A-505, and were flown with a free lift of 1600 grams. Their characteristics and flight performance are given in Table 112.

Analysis of these flights indicates that although the level of performance is low, it is quite consistent. It seems possible that the low altitudes may be due to an inherent lack of elongation in the compound.

Accordingly, compound A3-118 was designed in which the plasticizer content was increased by an additional 10 parts.

Five balloons from this compound were prepared and submitted for flight testing. These balloons were identified as EX-3A-511 through EX-3A-515. They were flown in the daytime with a free lift of 1600 grams. Their characteristics and flight performance are given in Table 113.

Analysis of these flights shows that consistency of performance has been maintained, and the average bursting elevation has been raised from 82,000 feet in the case of compound A3-115 to 89,500 feet for compound A3-118.

FACTUAL DATA (continued)

TASK A, Phase 4, Part A (continued)

TABLE 111

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-105

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-1201	W17-3	Day	1645	125	125,000	1090
EX-3A-1202	W17-4	Day	1645	121	125,919	1175
EX-3A-1203	W17-6	Day	1615	123	125,810	1135

TABLE 112

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-115

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-501	W10-8TK	Day	1000	107	75,900	1040
EX-3A-502	W14-2TK	Day	1010	105	84,300	1045
EX-3A-503	W14-3TK	Day	1020	107	88,000	1101
EX-3A-504	W14-4TK	Day	1020	105	84,000	1069
EX-3A-505	W15-2TK	Day	1035	108	77,800	1059

In order to improve the ozone resistance of the Lytron-containing compounds, N.B.C. had been replaced by Agerite DPPD in A3-115 and A3-118. It has already been shown that replacement of N.B.C. in compound A3-105 by Agerite DPPD in compound A3-117 resulted in a loss in daytime altitude of approximately 10,000 feet. (See Task B, Phase 5). This was attributed to the darker color of the balloons resulting in increased infra-red ratiation absorption.

It would seem probable, therefore, that A3-118, if the color were lighter, would provide a consistent 100,000-foot balloon.

A group of six balloons in the 2500-gram class made from compound A3-101 was flown. This compound had in the past given somewhat erratic results due, it was felt, to its low room-temperature modulus. The cure was therefore adjusted to increase the modulus, and this group of flights was conducted with balloons cured according to the revised procedure.

These balloons were identified as EX-3A-2011 through EX-3A-2016 and were flown with a free lift of 1600 grams. Their characteristics and the results of these flights are given in Table 114.

A study of these results shows that the consistency of this balloon's performance has been improved enormously. Of the six flights, five reached altitudes between 132,000 feet and 139,000 feet, and the sixth balloon reached an altitude of 126,000 feet. All six balloons had ascensional rates of over 1000 feet per minute.

Three balloons in the 1000-gram class were manufactured from compound A3-157. This compound was designed for exceptionally high elongation at room temperature and at -40°C. The characteristics of these balloons and their flight performance are given in Table 115.

The results obtained with these three balloons are excellent, both as to altitude attained and consistency of performance. In addition the ascensional rate is also satisfactory. It would seem, therefore, that the increased elongation has resulted as could be expected in a substantial gain in altitude (approximately 15,000 feet). If this level of performance can be maintained with larger balloons, 2500-gram balloons from this compound should consistently reach altitudes of more than 140,000 feet which would constitute a major advance for meteorological balloons.

FACTUAL DATA (continued)

TASK A, Phase 4, Part A (continued)

TABLE 113

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-118

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-511	A4-2TK	Day	1090	112	90,000	1146
EX-3A-512	A4-3TK	Day	1080	112	89,300	1104
EX-3A-513	A6-2TK	Day	1080	113	88,300	1141
EX-3A-514	A10-2TK	Day	1080	111	86,400	1119
EX-3A-515	A14-2TK	Day	1090	111	93,800	1089

TABLE 114

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-101

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-2011	F18-2	Day	2420	186	138,250	1088
EX-3A-2012	F19-2	Day	2475	196	139,108	1089
EX-3A-2013	F19-4	Day	2490	189	138,320	1069
EX-3A-2014	F19-5	Day	2615	196	126,312	1066
EX-3A-2015	F20-1	Day	2435	184	132,316	1076
EX-3A-2016	F20-5	Day	2630	192	134,744	1036

TABLE 115

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-157

Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
S18-2TB	Day	1010	98	122,828	1135
S18-3TB	Day	1030	102	124,672	1114
S18-7TB	Day	1000	103	123,491	1099

Part B: Dual-Purpose Balloons

Compound A3-103 showed good physical characteristics for a dual-purpose balloon. Accordingly, six balloons in the 600-gram class were prepared and submitted for flight testing. These balloons were flown at night with a total lift of 3200 grams. They were manufactured in January, 1960, at a time when Contract DA-36-039-SC-78239 had expired and Contract DA-36-039-SC-84925 had not yet been awarded. Characteristics of these balloons identified as EX-10 through EX-15, and their flight performance are recorded in Table 116.

A study of these results shows excellent performance as far as altitude is concerned. The rate of rise, however, is somewhat below the desired minimum of 1000 feet per minute.

In order to determine the storage characteristics of this compound and of these balloons, further balloons of the same weight and size were made from compound A3-103 after it had been allowed to age for four months. Three of these balloons were flown immediately, and three more were flown after being allowed to shelf age for two months.

Balloons EX-16, EX-17 and EX-18 were freshly made and were flown with a total lift of 3200 grams. Balloons EX-3A-105, EX-3A-106 and EX-3A-107 were aged for two months before flight and were flown with a total lift of 3400 grams.

TABLE 116

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-103

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-10	A7-3T	Night	655	85	97,800	932
EX-11	A7-4T	Night	645	87	100,000	980
EX-12	A11-3T	Night	665	86	100,700	955
EX-13	A12-3T	Night	650	85	82,200	924
EX-14	A13-1T	Night	635	86	100,600	998
EX-15	A13-2T	Night	685	86	101,300	972

At the same time, four balloons weighing approximately 750 grams were made from the aged compound. These balloons were identified as EX-3A-101 through EX-3A-104. They were flown with a total lift of 3600 grams. All of the above balloons were flown at night, and the characteristics and flight results are recorded in Table 117.

A study of these results shows that although there appears to be a reduction in performance as the compound ages, there is no loss in performance by the balloon after aging for two months.

All of the altitudes with the exception of EX-3A-102 are satisfactory, and the lighter weight balloons flown with a total lift of 3400 grams (EX-3A-105, EX-3A-106 and EX-3A-107) achieved rates of ascent in excess of 1000 feet per minute. Increasing the weight of the balloon to 750 grams was not accompanied by an increase in length, and consequently the higher lift of 3600 grams resulted in a loss of altitude.

The improved low-temperature characteristics of compound A3-104 suggested that it should yield good dual-purpose balloons. Accordingly, six balloons in the 750-gram class were submitted for flight testing. They were identified as EX-3A-301 through EX-3A-306, flown at night with a total lift of 3600 grams, and reported on in Table 118.

FACTUAL DATA (continued)

TASK A. Phase 4. Part B (continued)

TABLE 117

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-103

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Flaccid Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-16	C22-3T	Night	660	88	95,500	987
EX-17	C22-5T	Night	640	85	94,900	991
EX-18	C23-3T	Night	655	86	90,300	992
EX-3A-101	F22-1T	Night	735	87	98,200	1079
EX-3A-102	F25-1T	Night	740	87	56,900	662
EX-3A-103	F26-2T	Night	735	84	86,100	1013
EX-3A-104	F26-3T	Night	740	87	88,730	828
EX-3A-105	F19-1T	Night	675	86	92,900	1004
EX-3A-106	F19-3T	Night	680	85	92,420	1030
EX-3A-107	F19-4T	Night	690	89	95,500	1013

TABLE 118

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-104

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Flaccid Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-301	H10-1T	Night	710	79	90,500	1093
EX-3A-302	H11-2T	Night	730	80	89,600	1123
EX-3A-303	H17-1T	Night	730	75	91,100	1087
EX-3A-304	H17-3T	Night	755	80	72,200	953
EX-3A-305	H18-3T	Night	750	76	95,600	1116
EX-3A-306	H19-1T	Night	760	82	105,000	1066

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

A study of the results in Table 118 shows that this balloon performs satisfactorily at night. Comparison with flights EX-3A-101 through EX-3A-104 in Table 117 shows that the balloons made from compound A3-104 averaged 94,360 feet (eliminating the 72,200-foot flight) while the balloons made from compound A3-103 averaged 91,010 feet (eliminating the 56,900-foot flight).

Similarly, the average rate of ascent of the A3-104 balloons was 1097 feet per minute, while that of the A3-103 balloons was 973 feet per minute.

At the same time it must be noted that the A3-104 balloons had an average length of 78 inches while the A3-103 balloons had an average length of 86 inches.

Thus the superiority of compound A3-104 is clearly demonstrated, confirming the indication of the laboratory physical characteristics.

An additional seven balloons made from compound A3-104 were next flown. Four of these were in the 750/800-gram range, and were identified as EX-3A-311 through EX-3A-314. One balloon, EX-3A-1101, weighed about 1000 grams, and the remaining two weighed about 1700 grams. They were all flown with a free lift of 1600 grams. The characteristics of these balloons and their flight performance are given in Table 119.

Examination of these results shows that balloons in the 750/800-gram range perform satisfactorily, three out of four flights being over 100,000 feet. The single balloon in the 1000-gram class flown at night also performed well, reaching an altitude of 111,000 feet. The indications are,therefore, that compound A3-104 produces satisfactory dual-purpose balloons up to the 100,000-foot level.

However, the two 1700-gram balloons are disappointing. There is no immediately apparent reason for the failure of these balloons, particularly in view of the good performance of the smaller balloons, and further flights were therefore carried out.

A group of eight balloons was flown by both day and night with a free lift of 1600 grams. The characteristics of these balloons and their flight performance are given in Table 120.

Analysis of these results shows that six out of the eight flights reached altitudes in excess of 100,000 feet, and of the two that failed to do so, one of them reached 98,700 feet. The very slow rate of ascent of the eighth balloon suggests that it possibly developed a pinhole.

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

TABLE 119

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-104

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-311	S14-3TN	Day	775	80	100,600	1167
EX-3A-312	S19-1TN	Night	755	90	101,700	1059
EX-3A-313	S21-2TN	Night	780	80	67,000	1138
EX-3A-314	S21-3TN	Day	785	84	110,900	1225
EX-3A-1101	R 2-3T	Night	1105	99	108,300	1062
EX-3A-1102	M29-4T	Night	1740	133	66,000	927
EX-3A-1103	M29-5T	Night	1700	133	92,700	1055

TABLE 120

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-104

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-321	T5-2TM	Night	835	92	109,200	1073
EX-3A-322	T6-1TM	Day	810	92	103,200	1166
EX-3A-323	T11-2TK	Night	1050	103	109,950	1037
EX-3A-324	T14-1TK	Day	1025	106	98,700	1093
EX-3A-325	T14-3TK	Night	1055	100	72,000	686
EX-3A-326	T14-4TK	Day	1025	98	110,000	1117
EX-3A-327	T14-5TK	Night	1045	106	111,900	1015
EX-3A-328	T26-2TK	Day	1020	102	107,900	1024

It would appear, therefore, that compound A3-104 produces a satisfactory 100,000-foot balloon capable of flying by day or by night and having a satisfactory rate of ascent.

A series of balloons in the 1750-gram class was now made from compound A3-104. In all, sixteen balloons ranging in weight from 1750 grams to 2250 grams were flown.

The sixteen balloons were identified as EX-3A-1331 through EX-3A-1336 in the case of the 1750 gram class, and EX-3A-1111 through EX-3A-1115 and EX-3A-1531 through EX-3A-1535 in the case of the heavier balloons. All of the balloons were flown with a free lift of 1600 grams. The flight performance and characteristics of the balloons are given in Table 121.

It would appear from these results that this compound is suitable for high-altitude, day-flight balloons but not for night-flight balloons although it is designed as a dual-purpose compound and performs as such at the 100,000-foot level and below.

Additional flights were conducted with balloons manufactured from compound A3-104 which had been aged for six months. The balloons were flown with a free lift of 1600 grams, and the results of these flights are given in Table 122.

A study of these results shows that there is in general, no loss in performance with compound A3-104, and that it is capable of producing a consistent 100,000-foot balloon.

A further group of balloons was prepared from compound A3-104. These balloons weighed approximately 2000 grams. Balloons EX-3A-1541 through EX-3A-1543 ranged in length from 135 to 139 inches; balloons EX-3A-1544 through EX-3A-1546 ranged in length from 117 to 118 inches. They were all flown with a free lift of 1600 grams, and their characteristics and flight performance are given in Table 123.

A study of these results shows that, although compound A3-104 performs satisfactorily at the 100,000-foot level, it is erratic at the 120,000-foot level. Of the six flights, only one reached an altitude in excess of 120,000 feet.

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

TABLE 121

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-104

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-1331	C20-1T	Day	1805	128	119,160	1220
EX-3A-1332	C20-2T	Day	1775	134	113,852	1132
EX-3A-1333	C21-2T	Day	1870	131	134,350	1127
EX-3A-1334	C21-3T	Night	1850	132	not flown	
EX-3A-1335	C23-1T	Night	1760	128	92,100	965
EX-3A-1336	C23-2T	Night	1805	132	111,450	1018
EX-3A-1111	B23-1T	Night	2215	140	117,077	822
EX-3A-1112	B23-2T	Day	2220	139	105,000*	1094
EX-3A-1113	B27-1T	Day	2210	141	124,377*	1180
EX-3A-1114	B28-1T	Night	2225	140	72,800	915
EX-3A-1115	B28-2T	Night	2340	141	109,515	889
EX-3A-1531	C2-1T	Night	2290	143	83,400	940
EX-3A-1532	C6-1T	Night	2270	151	94,000	917
EX-3A-1533	C8-3T	Night	2300	148	98,200	919
EX-3A-1534	C1-1T	Night	2485	145	91,200	529
EX-3A-1535	C3-1T	Night	2680	160	122,300	901

* Top Intelligible Data

FACTUAL DATA (continued)

TABLE 122

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-104

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-451	F14-4M	Day	1050	85	97,600	1076
EX-3A-452	F14-8M	Night	1055	96	108,400	1134
EX-3A-453	F17-1M	Day	1005	87	99,400	1242
EX-3A-454	F17-2M	Night	975	88	100,100	1095
EX-3A-455	F17-5M	Day	1025	89	109,400	1240
EX-3A-456	F18-3M	Night	1005	84	108,300	1176
EX-3A-561	F28-3TM	Day	1025	99	106,900	1011
EX-3A-562	F28-4TM	Night	1010	109	112,500	983
EX-3A-563	F28-5TM	Night	1000	109	110,000	998
EX-3A-564	F28-6TM	Night	1025	106	108,600	1057
EX-3A-565	F28-7TM	Day	1035	108	105,600	1100
EX-3A-566	H1-6TM	Day	1030	101	110,000	1134
EX-3A-481	H12-2T	Night	1130	89	101,450	1061
EX-3A-482	H12-4T	Night	1085	109	103,800	1001
EX-3A-483	H15-5T	Night	1085	91	100,575	1001
EX-3A-521	H25-1TN	Night	1060	101	105,400	1033
EX-3A-522	H25-2TN	Day	1050	102	102,400	1073
EX-3A-523	H26-5TN	Night	1060	105	105,900	1012
EX-3A-524	H29-1TN	Day	1000	104	106,900	1058
EX-3A-525	H29-7TN	Night	1010	105	105,600	979
EX-3A-526	K1-2TN	Day	1040	104	107,100	1030

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

TABLE 123

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-104

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-1541	F5-2T	Day	2145	135	125,700	1136
EX-3A-1542	F5-3T	Night	2115	139	111,415	991
EX-3A-1543	F7-3T	Day	2205	138	98,870	1030
EX-3A-1544	F25-4	Day	2200	117	113,058	1184
EX-3A-1545	F26-5	Night	2105	117	104,920	913
EX-3A-1546	F26-6	Night	2175	118	100,600	946

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

The performance of the balloon is little affected by the length. This seems to indicate that the additional pre-elongation which the smaller balloon achieves before entering the low-temperature zones compensates for the shorter length, and therefore points to the fact that the freeze resistance of this compound was satisfactory for a balloon 105 inches long designed to reach an altitude of 100,000 feet but was insufficient for a larger balloon designed to reach higher altitudes.

In order to confirm the performance of compound A3-30-1, the dual-purpose compound developed during Contract DA-36-039-SC-78239, additional flights were performed with 1000-gram balloons. These flights were conducted after the expiration of Contract DA-36-039-SC-78239, and before the award of Contract DA-36-039-SC-84925. In all, eighteen balloons were flown. They were identified as EX-21 through EX-38 and were flown with a free lift of 1600 grams. Fifteen were flown during the night, and three were flown during the day. The characteristics of these balloons and their flight performance are given in Table 124.

Analysis of these results shows that the three day-flight balloons reached altitudes in excess of 100,000 feet. Of the fifteen night-flight balloons, eleven (73%) reached altitudes in excess of 100,000 feet.

In view of the performance of this compound, it was decided to use it to manufacture larger balloons as part of this study. The compound was therefore assigned the number A3-106, and the balloons in the 1750-gram and 3000-gram class were manufactured.

Initially, three 3000-gram balloons were submitted for flight testing. These balloons were identified as EX-50, EX-51 and EX-52. They were flown during the hours of darkness with a free lift of 1600 grams. Characteristics of these balloons and the flight results are recorded in Table 125.

A study of these results shows consistent performance insofar as altitude is concerned. Although the ascensional rate is less than that desirable.

A further six balloons were submitted, three of which were flown during the hours of darkness and three during the hours of daylight. These balloons were identified as EX-3A-2101 through EX-3A-2106. All balloons were flown with a free lift of 1600 grams. The characteristics of these balloons and their flight performance are also given in Table 125.

TABLE 124

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-106

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Flaccid Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-21	B10-2	Night	1205	109	114,000	1071
EX-22	B10-3	Night	1195	102	96,610	986
EX-23	B10-4	Night	1220	112	116,699	1058
EX-24	B10-5	Night	1150	108	110,000	996
EX-25	B10-6	Night	1225	110	114,500	1073
EX-26	B10-10	Night	1180	116	114,403	1142
EX-27	B18-2T	Night	1105	102	92,700	1010
EX-28	B18-5T	Night	1110	103	96,500	948
EX-29	B19-7T	Day	1070	99	101,800	931
EX-30	B19-8T	Day	1100	102	101,000	1069
EX-31	B23-1T	Day	1080	108	114,000	1145
EX-32	B23-3T	Night	1115	106	112,008	1085
EX-33	C18-6	Night	1135	114	109,055	980
EX-34	C18-7	Night	1050	106	39,500	741
EX-35	C18-8	Night	1110	107	104,000	985
EX-36	C18-9	Night	1105	111	103,117	1023
EX-37	C18-10	Night	1085	110	105,479	986
EX-38	C18-11	Night	1085	107	106,102	1064

TABLE 125

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-106

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Flaccid Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-50	B23-2	Night	3025	188	110,302	815
EX-51	B24-3	Night	2925	174	126,472	791
EX-52	A19-2	Night	2950	186	126,476	817
EX-3A-2101	A19-3	Night	2950	184	137,369	905
EX-3A-2102	A20-1	Day	3000	183	90,000	909
EX-3A-2103	A20-2	Night	2850	181	122,966	854
EX-3A-2104	A20-2	Day	2975	180	113,714	980
EX-3A-2105	A21-2	Night	3050	182	140,682	962
EX-3A-2106	A23-1	Day	2900	188	133,005	1015
EX-3A-2107	A23-2	Day	3025	186	64,200	789
EX-3A-2108	A25-1	Day	2950	179	134,843	1040
EX-3A-2109	A25-3	Day	3150	189	61,300*	841

* Top Intelligible Data

Analysis of these results again reveals erratic daytime performance, although the picture is less clear because of the instrument failure recorded. It would appear that although a satisfactory high altitude, night-flight balloon had been developed, additional work on the compound is necessary to obtain a dual-purpose, high-altitude balloon.

The flight performance of 1750-gram balloons made from the same compound was next investigated. Six balloons were submitted for flight test. These were identified as EX-3A-1004 through EX-3A-1009. Three were flown during the day and three at night, all with a free lift of 1600 grams. The characteristics of these balloons and their flight performance are given in Table 126.

Analysis of these flights indicates that satisfactory performance at 120,000 feet can be obtained with a 1750-gram balloon made from compound A3-106. The rate of ascent is a little slow, but is much better than that of the 3000-gram balloons. Shortening the balloon should correct this condition and increase the rate of rise to over 1000 feet per minute.

In order to complete the performance pattern of balloons made from this compound, three balloons in the 700-gram class and six in the 600-gram class were prepared. These were identified as EX-3A-201, EX-3A-202 and EX-3A-203, and EX-3A-211 through EX-3A-216.

Balloons EX-3A-201 through EX-3A-203 were flown during the hours of daylight with a total lift of 3600 grams. Balloons EX-3A-213, EX-3A-215 and EX-3A-216 were flown during the daylight hours with a total lift of 3400 grams; and balloons EX-3A-211, EX-3A-212 and EX-3A-214 were flown during the hours of darkness also with a total lift of 3400 grams. The characteristics of these balloons and their flight performance are given in Table 127.

A study of these results shows that this compound yields a very satisfactory balloon in the 600-gram to 700-gram range. It may be concluded, therefore, that dual-purpose in the weight range of 600 grams to 1750 grams can be made from compound A3-106 and that they will all perform reliably at the altitudes for which they are intended.

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

TABLE 126

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-106

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Flaccid Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-1004	H18-1	Night	1700	138	128,543	968
EX-3A-1005	H18-2	Night	1750	139	130,512	967
EX-3A-1006	H18-3	Night	1675	142	128,051	983
EX-3A-1007	H18-4	Day	1750	146	135,466	1132
EX-3A-1008	H19-1	Day	1790	147	96,090	910
EX-3A-1009	H19-4	Day	1880	143	127,395	1037

TABLE 127

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-106

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Flaccid Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-201	K131	Day	740	92	104,400	1143
EX-3A-202	K132	Day	745	95	101,800	1095
EX-3A-203	K133	Day	770	96	93,800	1123
EX-3A-211	K71	Night	640	92	100,200	955
EX-3A-212	K81	Night	630	90	104,000	1024
EX-3A-213	K101	Day	630	91	82,400	988
EX-3A-214	K121	Night	625	86	91,300	950
EX-3A-215	K141	Day	645	89	101,100	1071
EX-3A-216	K161	Day	680	94	103,600	1085

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

In order to confirm the performance of the 120,000-foot balloon, a further and more extended series of flights was made with balloons made from compound A3-106 and weighing 1800 grams to 2000 grams. In all, twenty-one balloons were flown with a free lift of 1600 grams. Balloons EX3A-1211 through EX-3A-1213 and balloons EX-3A-1251 through EX-34-1256 were given additional cure.

The characteristics of these balloons and their flight performance are given in Table 128.

Analysis of these results shows that out of nine day-flights, only five reached altitudes greater than 120,000 feet although eight were above 110,000 feet. This is fairly good performance although it was expected that better results would be obtained.

However, at night only one balloon reached an altitude greater than 120,000 feet and only two were above 110,000 feet. Three balloons, EX-3A-1222, EX-3A-1224 and EX-3A-1226 appeared to freeze, although laboratory tests of the film show that it does not freeze at -70°C.

The failure of this compound to provide a reliable 120,000-foot balloon, particularly at night, calls for further investigation since it has provided a very consistent and reliable 100,000-foot balloon.

Six balloons were made from compound A3-106 using a new dipping form designed to produce a nominal 2000-gram balloon. These balloons were identified as EX-3A-1501 through EX-3A-1506 and were flown with a free lift of 1600-grams. Their characteristics and flight performance are given in Table 129.

Analysis of these results shows the same lack of consistency as was exhibited by balloons made on the 1500-gram form. Although part of the poor performance may be ascribed to the new form, it nevertheless confirms the failings of A3-106 for balloons for use above 100,000 feet.

Six balloons were therefore made from a newly compounded batch of A3-106 and submitted for flight testing. These balloons which were in the 1750-gram class were identified as EX-3A-1241 through EX-3A-1246 and were all flown with a free lift of 1600 grams. The characteristics of these balloons and their flight performance are given in Table 130.

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

TABLE 128

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-106

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Flaccid Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-1211	W18-4	Night	1865	132	74,000	983
EX-3A-1212	W18-5	Night	1820	133	104,823*	944
EX-3A-1213	W18-6	Night	1845	132	95,420*	823
EX-3A-1221	W16-2	Day	1905	132	122,343	1104
EX-3A-1222	W16-3	Night	1870	128	65,800	896
EX-3A-1223	W16-4	Day	1865	130	115,000	1047
EX-3A-1224	W16-6	Night	1875	133	51,600	885
EX-3A-1225	W17-2	Day	1915	132	123,800**	1133
EX-3A-1226	W17-5	Night	1935	130	59,200	940
EX-3A-1231	Y8-2	Night	1935	146	123,163	894
EX-3A-1232	Y8-4	Night	1905	143	84,220	898
EX-3A-1233	Y8-5	Night	1880	145	73,400	667
EX-3A-1234	Y8-6	Day	1980	143	127,986	1020
EX-3A-1235	Y13-2	Day	1885	143	131,726	1076
EX-3A-1236	Y15-4	Day	1915	137	107,776	1094
EX-3A-1251	Y15-2	Day	2100	139	118,077	1070
EX-3A-1252	Y15-3	Night	2040	134	112,110	918
EX-3A-1253	Y15-6	Day	2040	142	111,975	1020
EX-3A-1254	Y16-5	Night	2090	144	94,910	841
EX-3A-1255	Y21-2	Night	2050	146	106,693	884
EX-3A-1256	Y21-3	Day	2010	147	120,653	1021

* Balloon floated

**T.I.D.

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

TABLE 129

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-106

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-1501	W21-2	Day	2695	150	112,303	1027
EX-3A-1502	W25-1	Night	2300	154	87,150	846
EX-3A-1503	W25-2	Day	2270	158	55,200	847
EX-3A-1504	W25-3	Night	2345	155	94,200	915
EX-3A-1505	W25-4	Night	2200	152	85,500	885
EX-3A-1506	W26-1	Day	2335	159	119,915	1048

TABLE 130

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-106

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-1241	A19-2	Day	1920	134	97,600	1043
EX-3A-1242	A19-4	Night	1985	135	105,610	822
EX-3A-1243	A19-5	Night	1950	137	launching reel failure	
EX-3A-1244	A24-2	Night	1830	133	launching reel failure	
EX-3A-1245	A25-2	Night	1860	132	110,300	962
EX-3A-1246	A25-3	Day	1840	133	116,634	1073

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

A study of these results shows that the performance of these balloons is still unsatisfactory. In order to improve the freeze resistance, compound A3-121 was designed, and six balloons in the 2000-gram class were made and submitted for flight testing. These balloons were identified as EX-3A-1261 through EX-3A-1266. They were flown with a free lift of 1600 grams, and their characteristics and flight performance are given in Table 131.

A study of these results shows that this formulation change has not resulted in any improvement in flight. These balloons were very soft and presented some problems in handling.

Accordingly, six balloons were made from compound A3-122 which has similar low-temperature characteristics to A3-121, but is somewhat stronger and easier to handle. These balloons were also in the 2000-gram class and were identified as EX-3A-1271 through EX-3A-1276. They were flown with a free lift of 1600 grams. Their characteristics and flight performance are given in Table 132.

A study of these results shows that although there is some improvement in altitude and the flights are more consistent, the 120,000-foot level is still not being achieved.

A further change in plasticizer content was therefore made, and two compounds which used a combination of Dibutyl Sebacate, Butyl Oleate and Paraflux C-325, were designed; compound A3-123 having five parts more plasticizer than compound A3-124.

Six balloons of the 1750-gram class were made from each of these compounds. Those made from compound A3-124 were identified as EX-3A-1281 through EX-3A-1286, and those made from compound A3-124 were identified as EX-3A-1291 through EX-3A-1296. They were all flown with a free lift of 1600 grams, and the characteristics of these balloons and their flight performance are given in Table 133.

A study of the above results shows that the variation in plasticizer content has no effect on the altitudes reached; and the general performance level is still unsatisfactory, being poorer than that of balloons made from compound A3-122.

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

TABLE 131

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-121

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-1261	Y1-3	Day	2010	139	103,904	987
EX-3A-1262	Y1-4	Night	2075	135	88,200	865
EX-3A-1263	Y1-5	Day	1990	133	109,800	1052
EX-3A-1264	Y1-6	Night	2035	138	100,600	915
EX-3A-1265	Y2-3	Night	2090	138	87,880	908
EX-3A-1266	Y2-5	Day	2035	140	instrument	failure

TABLE 132

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-122

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-1271	Y7-4	Day	2015	144	121,309	1115
EX-3A-1272	Y7-5	Night	1915	137	instrument	failure
EX-3A-1273	Y7-6	Day	1985	145	107,800	1038
EX-3A-1274	Y13-3	Day	1925	140	118,695	1062
EX-3A-1275	Y19-3	Night	2120	146	114,500	897
EX-3A-1276	Y21-5	Night	2140	153	118,200	920

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

TABLE 133

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUNDS A3-123 AND A3-124

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-1281	A31-2	Night	1825	133	70,800	954
EX-3A-1282	B1-1	Day	1920	140	119,816	1075
EX-3A-1283	B1-2	Night	1800	137	81,000	892
EX-3A-1284	B1-4	Day	1805	137	119,065	1096
EX-3A-1285	B1-5	Night	1925	138	70,800	919
EX-3A-1286	B3-4	Day	1900	141	71,500	850
EX-3A-1291	B8-4	Night	2030	145	96,260	900
EX-3A-1292	B13-2	Night	1915	143	98,130	905
EX-3A-1293	B13-3	Day	1855	140	89,400	982
EX-3A-1294	B13-4	Night	1930	144	73,880	845
EX-3A-1295	B14-2	Day	1855	140	102,000*	-
EX-3A-1296	B17-2	Day	1845	140	119,885	1079

*Top Intelligible Data

FACTUAL DATA (continued)

TASK A. Phase 4. Part B (continued)

Two additional compounds were now prepared in which the antiozonant was increased from three parts to five parts. It is well known that the ozone resistance of a highly plasticized neoprene compound is very low and the standard amount of three parts may be insufficient to provide sufficient protection for a balloon required to fly substantially higher than the normal altitude of maximum ozone concentration. Compound A3-125 had the same plasticizer content as compound A3-124 and compound A3-126 had the same plasticizer content as A3-123.

Six balloons were made from each of these compounds, all in the 1750-gram class. The balloons made from compound A3-125 were identified as EX-3A-1301 through EX-3A-1306, and those made from compound A3-126 were identified as EX-3A-1311 through EX-3A-1316. They were all flown with a free lift of 1600 grams. Their characteristics and flight performance are given in Table 134.

A study of these results indicates a possibly slight improvement over the results obtained with balloons made from compounds A3-123 and A3-124 and also that the amount of plasticizer makes relatively little difference. The performance is still unsatisfactory, and does not equal that obtained with balloons made from compound A3-122.

Examination of all the results obtained thus far showed that the balloons made from compound A3-122 were somewhat heavier, being in the 2000-gram class. Since the lengths of the balloons were all approximately equal, the heavier balloon must have a slightly thicker wall, and hence be somewhat more rugged.

In order to determine the extent to which the increased wall thickness affected the flight, six balloons in the 2500-gram class were made from compound A3-123 and six balloons from compound A3-124. The balloons made from A3-124 were identified as EX-3A-1521 through EX-3A-1526. They were all flown with a free lift of 1600 grams, and their characteristics and flight performance are given in Table 135.

A study of these results shows a marked improvement in performance. There is little to choose between the two compounds represented by these flights; and considering the ten completed flights, nine (90%) reached altitudes of more than 110,000 feet, and six (60%) reached altitudes of more than 120,000 feet. This performance may be considered satisfactory.

FACTUAL DATA (continued)

TABLE 134

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUNDS A3-125 AND A3-126

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-1301	B21-2	Day	1820	134	76,800	982
EX-3A-1302	B21-5	Night	1835	137	95,200*	878
EX-3A-1303	B23-2	Day	1860	135	108,773	1064
EX-3A-1304	B23-5	Day	2020	145	121,155	1070
EX-3A-1305	B24-3	Night	1760	134	104,724	935
EX-3A-1306	C1-2	Night	1850	133	105,249	943
EX-3A-1311	B21-3	Day	1890	138	84,000	1002
EX-3A-1312	B21-4	Night	1865	133	99,620	891
EX-3A-1313	B24-2	Night	1885	132	100,000*	862
EX-3A-1314	C2-2	Night	1880	138	67,100	741
EX-3A-1315	C2-4	Day	1980	144	120,505	1116
EX-3A-1316	C2-5	Day	1945	137	114,872	1084

*Approximate

TABLE 135

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUNDS A3-124 AND A3-123

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-1511	B2-2	Night	2285	130	82,000	1035
EX-3A-1512	B3-2	Night	2335	132	instrument	failure
EX-3A-1513	B7-4	Night	2390	133	121,260	974
EX-3A-1514	B8-1	Night	2345	134	110,200	879
EX-3A-1515	B9-4	Day	2425	136	128,600	1162
EX-3A-1516	B17-3	Day	2265	136	125,000	1140
EX-3A-1521	B8-2	Day	2375	133	115,092	1083
EX-3A-1522	B10-1	Day	2310	135	124,245	1195
EX-3A-1523	B10-3	Night	2565	136	121,000	975
EX-3A-1524	B10-4	Day	2535	145	53,000*	962
EX-3A-1525	B14-4	Night	2540	146	110,000	909
EX-3A-1526	B15-4	Day	2480	144	128,740	1127

*Top Intelligible Data

It appears, therefore, that increasing the weight, and thereby the wall thickness of the balloon has assisted in improving flight performance more materially than any other change made. In order to confirm this, a further compound was prepared in which the antiozonant percentage was raised still further.

Six balloons in the 1750-gram class were made from this compound designated as A3-127 as well as six in the 2000-gram class. The 1750-gram balloons were identified as EX-3A-1341 through EX-3A-1346, and the 2000-gram balloons were identified as EX-3A-1351 through EX-3A-1356.

As controls, six balloons in the 1750-gram class made from compound A3-106 and identified as EX-3A-1321 through EX-3A-1326 were flown at the same time. All balloons were flown with a free lift of 1600-grams. The characteristics of these balloons and their flight performance are recorded in Table 136.

A study of these results shows that the heavier balloons out performed the lighter balloons of both types to a marked degree. It would appear, therefore, that it is necessary to increase the wall thickness of balloons as the size of the balloon increases.

Compound A3-127 has been used to produce satisfactory 120,000-foot balloons. This compound is similar to A3-106 but has a higher plasticizer content. In order to confirm the performance of this compound, a further twelve balloons in the 1800/2000 gram range were submitted for flight testing.

Since it has been demonstrated that a compound suitable for 100,000-foot balloons is not necessarily suitable for 120,000-foot balloons, it was considered of interest to see if the reverse was also true -- that a compound suitable for 120,000-foot balloons was not suitable for 100,000-foot balloons.

Accordingly, six balloons in the 1000-gram class were manufactured from compound A3-127 and submitted for flight testing. All balloons in this series were flown with a free lift of 1600 grams. The characteristics and flight results are given in Table 137.

TABLE 136

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUNDS A3-127 AND A3-106

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-1321	Y16-4	Night	1980	140	51,700	879
EX-3A-1322	Y19-2	Day	1890	137	42,700	909
EX-3A-1323	Y19-4	Day	1930	136	126,640	1119
EX-3A-1324	Y20-1	Night	1800	135	50,400	892
EX-3A-1325	Y20-2	Night	1825	132	97,790	940
EX-3A-1326	Y20-3	Day	1835	133	118,865	1128
EX-3A-1341	C20-3	Day	1975	147	104,856	1014
EX-3A-1342	C20-4	Day	1970	148	89,200	956
EX-3A-1343	C20-5	Night	2040	148	11,600	520
EX-3A-1344	C30-4	Night	2145	150	65,600	692
EX-3A-1345	C29-2	Day	2145	148	115,551	1079
EX-3A-1346	C22-6	Night	1980	145	111,909	917
EX-3A-1351	C28-4	Day	2300	150	125,459	1173
EX-3A-1352	C22-5	Day	2125	152	123,097	1086
EX-3A-1353	C29-5	Day	2415	150	118,766	1162
EX-3A-1354	C21-4	Night	2330	150	131,004	964
EX-3A-1355	C30-1	Night	2285	148	121,424	978
EX-3A-1356	C30-3	Night	2410	152	113,287	916

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

TABLE 137

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-127

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-531	K2-4AM	Night	1110	118	105,600	976
EX-3A-532	K5-2AM	Night	1120	117	108,900	923
EX-3A-533	K5-3AM	Day	1105	116	103,400	961
EX-3A-534	K5-4AM	Night	1080	116	99,600	927
EX-3A-535	K5-5AM	Day	1115	116	75,300	873
EX-3A-536	K5-6AM	Day	1115	118	105,000	963
EX-3A-1361	H4-1A	Day	1785	130	129,331	1115
EX-3A-1362	H4-2A	Night	1795	131	120,635	1145
EX-3A-1363	H4-3A	Day	1955	136	127,160	1180
EX-3A-1364	H4-4A	Night	1775	130	119,270	1090
EX-3A-1365	H4-5A	Day	2010	135	116,765	1115
EX-3A-1366	H4-6A	Night	1895	141	75,600	911
EX-3A-1371	K23-3TR	Day	1930	157	117,946	1044
EX-3A-1372	K23-5TR	Day	1950	154	119,935	1060
EX-3A-1373	K27-3TR	Day	1950	159	122,635	1040
EX-3A-1374	K27-4TR	Night	1935	158	96,260	866
EX-3A-1375	K27-5TR	Night	1900	160	119,718	1000
EX-3A-1376	K29-3TR	Night	1960	160	129,593	1012

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

A study of these results shows that the flight performance of A3-127 at the 120,000-foot level has been confirmed, although these balloons are lighter in weight than were the previous group. Of the twelve flights, ten reached altitudes in excess of 110,000 feet. Although only five reached altitudes of over 120,000 feet, three others reached altitudes between 119,000 and 120,000 feet; and it may therefore be concluded that this compound will produce a balloon capable of reaching 120,000 feet at least 60% of the time.

However, the performance of the 1000-gram balloons is in no way superior to that of similar balloons manufactured from compound A3-106. As might be expected, the rate of ascent is slower and there is no compensating increase in altitude. In addition, these balloons proved to be difficult to handle on the ground, having inflated lengths prior to release on the order of 140 inches.

It seems clear, therefore, that a compound designed to produce balloons capable of reaching 120,000 feet or more is not necessarily a suitable compound for balloons designed to go to a lower level.

In order to confirm that compound A3-106 still provided satisfactory balloons at the 800-gram and 1000-gram size, additional flights were prepared with this type of balloon. In this first series, fourteen flights were conducted.

Balloons EX-3A-421 through EX-3A-426 were in the 800-gram class; balloons EX-3A-411 through EX-3A-414 were in the 1000-gram class; and balloons EX3A-401 through EX-3A-404 were in the 1200-gram class. All balloons were flown with a free lift of 1600 grams. The characteristics of these balloons and their flight performance are given in Table 138.

Examination of these results shows that compound A3-106 is still producing dual-purpose balloons which perform satisfactorily up to 100,000 feet. It is interesting to note, however, that comparison of the 800-gram balloon indicates that A3-104 is slightly superior in performance at this weight.

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

TABLE 138

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-106

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-421	R31-1T	Night	860	88	98,000	1214
EX-3A-422	R31-2T	Night	850	92	90,220	1096
EX-3A-423	R31-3T	Day	815	89	102,526	1055
EX-3A-424	R31-4T	Night	780	91	97,100	1095
EX-3A-425	R31-5T	Day	810	91	95,900	1026
EX-3A-426	R31-6T	Day	835	88	95,600	1095
EX-3A-411	S101-T	Night	985	105	104,500*	1045
EX-3A-412	S102-T	Day	985	109	108,000	1139
EX-3A-413	S103-T	Night	995	102	112,300	1046
EX-3A-414	S104-T	Day	1020	109	116,900	1135
EX-3A-401	R9-3T	Night	1175	121	110,700	987
EX-3A-402	R9-5T	Day	1205	118	67,120*	1070
EX-3A-403	R9-7T	Day	1165	115	72,300*	1040
EX-3A-404	R9-8T	Night	1165	113	129,246	1128

* Top Intelligible Data

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

It has never been clearly established that the balloon film should be cured to the optimum physical properties in order to provide optimum flight performance, although such an assumption would seem to be reasonable.

It was, therefore, decided to submit a series of balloons, all weighing approximately 1000 grams and with lengths of 105-115 inches, in groups which have been given lower cures than is normal for compound A3-106. In all, 28 balloons consisting of five groups were submitted for test.

Balloons EX-3A-421 through EX-3A-436 were standard balloons given the normal cure of 120 minutes at 280°F, with lengths at the maximum range.

Balloons EX-3A-441 through EX-3A-446 were also standard balloons having standard cure, but their lengths were at the minimum of the range.

Balloons EX-3A-461 through EX-3A-464 were manufactured from a compound freshly prepared and were otherwise similar to the first two groups.

Balloons EX-3A-465 through EX-3A-470 were cured for 75 minutes, and balloons EX-3A-471 through EX-3A-476 were cured for 90 minutes at 280°F.

All balloons in this series were flown with a free lift of 1600 grams. The results of the flights are given in Table 139.

A study of this table shows that no improvement is obtained by reduction of the cure to 90 minutes or to 75 minutes. In fact, indications are that the 75-minute cure results in inferior flight performance.

Use of a freshly prepared compound results in no improvement. The balloons of approximately 115-inch length were slightly superior to the 105-inch length balloons as far as altitude is concerned although, as was to be expected, the rate of ascent was slightly lower. There is, however, no very significant difference between the performance of these two groups.

TABLE 139

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-106

Experiment No.	Balloon No.	Cure Time (mins)	Cure Temp. (°F)	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-431	C-1T	120	280	Night	1000	115	99,800	1045
EX-3A-432	C-2T	120	280	Day	1030	114	113,750	1034
EX-3A-433	C-3T	120	280	Night	1005	115	110,800	1036
EX-3A-434	C-4T	120	280	Day	1005	115	107,400	1048
EX-3A-435	C-5T	120	280	Night	1005	115	104,700	1014
EX-3A-436	C-6T	120	280	Day	1000	114	113,300	968
EX-3A-441	F14-1T	120	280	Day	970	106	100,000	1047
EX-3A-442	F14-2T	120	280	Night	985	107	56,700	778
EX-3A-443	F14-3T	120	280	Day	995	105	104,400	1083
EX-3A-444	F14-4T	120	280	Night	965	101	107,900	1035
EX-3A-445	F14-5T	120	280	Day	975	104	108,500	1088
EX-3A-446	F14-6T	120	280	Night	985	106	107,950	1009
EX-3A-461	F28-8	120	280	Night	1025	105	102,500	1009
EX-3A-462	F28-9	120	280	Day	1005	98	8,900	654
EX-3A-463	F28-10	120	280	Day	1060	100	98,100	1073
EX-3A-464	F28-11	120	280	Night	1050	105	100,500	1003
EX-3A-465	21	75	280	Night	1100	112	102,000	932
EX-3A-466	25	75	280	Day	1080	107	102,800	1064
EX-3A-467	30	75	280	Day	1100	110	95,750	999
EX-3A-468	32	75	280	Day	1035	112	101,200	1016
EX-3A-469	38	75	280	Day	1030	107	84,750	1070
EX-3A-470	39	75	280	Night	1075	114	98,700	926
EX-3A-471	H11-1T	90	280	Day	1040	104	100,120	1123
EX-3A-472	H11-2T	90	280	Night	1065	106	56,100	940
EX-3A-473	H11-3T	90	280	Day	1055	103	103,320	951
EX-3A-474	H11-4T	90	280	Night	1025	107	97,600	957
EX-3A-475	H11-5T	90	280	Day	1065	105	101,800	1037
EX-3A-476	H11-6T	90	280	Night	1100	107	100,750	913

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

A further set of flights was conducted in which three groups of balloons were flown, each group consisting of six balloons. Balloons EX-3A-561 through EX-3A-566 were standard balloons which received the standard cure; balloons EX-3A-567 through EX-3A-572 were cured for two hours at 260°F; and balloons EX-3A-573 through EX-3A-578 had approximately 10% greater wall thickness.

Three balloons from each group were flown during the day, and three were flown at night. A free lift of 1600 grams was employed for all flights. The characteristics of these balloons and their flight results are given in Table 140.

A study of this table shows that the general level of performance of all these balloons is decidely below that usually obtained with balloons made from compound A3-106. Of eighteen flights, only eight reached altitudes in excess of 100,000 feet, and the rates of ascent were extremely slow.

Two additional groups of balloons made from compound A3-106 and weighing approximately 900 grams were prepared.

Balloons EX-3A-731 through EX-3A-736 were cured at 240°F, and balloons EX-3A-737 through EX-3A-742 were cured at 260°F. The normal curing temperature for this compound is 280°F.

These balloons were all flown at night with a free lift of 1600 grams. Their physical characteristics and flight performance are given in Table 141.

A study of these results indicates that reduction of the cure temperature to 240°F, has good potential as far as increasing the altitude attainable by this type of balloon is concerned. Four of the six flights are in excess of 120,000 feet. The rate of ascent of these four balloons is also satisfactory, the two balloons that failed to reach 100,000 feet being the only two with slow rates of ascent.

The results, however, do suggest that the performance of these balloons might be erratic.

Finally one further series of flights was conducted with balloons made from compound A3-106 and cured at a low temperature. In this series three additional balloons were made from compound A3-105 which was also cured at the same low temperature, these balloons, of course, being flown in the day-time.

TABLE 140

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-106

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-561	M17-1T	Night	985	110	14,500	833
EX-3A-562	M17-2T	Day	1090	112	100,200	937
EX-3A-563	M17-3T	Day	1045	108	95,240	904
EX-3A-564	M17-4T	Day	1035	110	96,000	1007
EX-3A-565	M17-5T	Night	1015	107	109,700	956
EX-3A-566	M17-6T	Night	1060	110	99,100	923
EX-3A-567	M26-1T	Day	1045	104	102,400	1021
EX-3A-568	M26-2T	Night	1110	108	97,790	939
EX-3A-569	M26-3T	Day	1050	107	105,300	986
EX-3A-570	M26-4T	Night	1095	108	54,900	678
EX-3A-571	M26-5T	Day	1105	107	101,300	968
EX-3A-572	M26-6T	Night	1095	106	100,500	925
EX-3A-573	M31-1T	Day	1185	110	97,300	925
EX-3A-574	M31-2T	Night	1200	112	98,680	934
EX-3A-575	M31-3T	Day	1210	109	89,800	912
EX-3A-576	M31-4T	Night	1195	112	102,400	873
EX-3A-577	M31-5T	Day	1210	111	70,000	955
EX-3A-578	M31-6T	Night	1195	107	124,500	1098

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

TABLE 141

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-106

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-731	H9-51T	Night	960	98	118,100	1012
EX-3A-732	H9-52T	Night	845	96	119,619	1111
EX-3A-733	H9-53T	Night	945	98	97,450	969
EX-3A-734	H9-54T	Night	1010	101	78,100	835
EX-3A-735	H9-55T	Night	905	98	127,848	1114
EX-3A-736	H9-56T	Night	815	97	120,270	1040
EX-3A-737	H10-1T	Night	980	96	105,741	1044
EX-3A-738	H10-2T	Night	970	97	113,681	1054
EX-3A-739	H10-3T	Night	915	95	97,790	1008
EX-3A-740	H10-4T	Night	975	95	107,316	1057
EX-3A-741	H10-5T	Night	915	96	64,100	986
EX-3A-742	H10-6T	Night	935	95	105,052	1020

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

Balloons EX-3A-772 and EX-3A-776 were made from compound A3-105 and cured for 60 minutes at 240°F. Balloon EX-3A-778 was also made from compound A3-105 and cured for 60 minutes at 260°F.

Balloons EX-3A-771, EX-3A-773, EX-3A-774 and EX-3A-775 were made from compound A3-106 and cured for 60 minutes at 240°F. Balloon EX-3A-777 was made from compound A3-106 and cured for 60 minutes at 260°F.

The physical characteristics of these balloons and their flight performance are given in Table 142.

A study of these results confirms that unusually high altitudes can be obtained by reducing the state of cure. In the case of compound A3-105 the performance appears to be quite consistent. In the case of compound A3-106, however, there are again indications that the reduced cure results in balloons that are erratic in their performance.

Compound A3-101, the number assigned to the compound developed during the interval between contracts and containing 10 parts of Dibutyl Sebacate, gave very good 2500-gram balloons; but the performance level of 1500-gram balloons was disappointing (see Task A, Phase 4, Part A). The plasticizer level was raised to 25 parts in order to check the performance of this compound in night-flight balloons, this latter compound being designated A3-107.

Six 3000-gram balloons were submitted for flight testing. These balloons were identified as EX-61 through EX-66. They were all flown during the hours of darkness with a free lift of 1600 grams. The characteristics of these balloons and their flight performance are given in Table 143.

A study of these results shows that four of the six flights reached altitudes in excess of 120,000 feet, while three of these were in excess of 140,000 feet. Balloon EX-63 established a new world's record for a night-flight balloon, and balloons EX-62 and EX-66 were also well above the previous record.

In view of this promising performance, a further six balloons were prepared and submitted for flight testing.

FACTUAL DATA (continued)

TABLE 142

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUNDS A3-106 AND A3-105

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-771	R10-1TW	Day	945	101	102,000	1059
EX-3A-772	R10-2TW	Day	855	92	122,211	1142
EX-3A-773	R10-3TW	Day	905	97	115,945	1120
EX-3A-774	R10-4TW	Night	985	100	84,760	1036
EX-3A-775	R10-5TW	Night	1005	100	96,770	1098
EX-3A-776	R10-6TW	Day	870	92	116,043	1103
EX-3A-777	R15-3TW	Night	970	102	115,420	1045
EX-3A-778	R20-13TW	Day	805	90	118,963	1152

TABLE 143

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-107

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-61	B 9-4	Night	3150	198	40,500	942
EX-62	B11-1	Night	3300	200	142,126	824
EX-63	B11-2	Night	3150	200	144,259	897
EX-64	B17-4	Night	3025	194	128,084	844
EX-65	B17-5	Night	3200	200	100,600	470
EX-66	B18-1	Night	3050	203	142,848	1058

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

These balloons proved impossible to handle having an extremely low modulus which resulted in excessive distortion in the inflation shelter followed by ground bursts. Upon investigation, it was discovered that an error had occured in processing which accounted for the deterioration of the balloon film. These balloons which were identified as EX-3A-2001 through EX-3A-2006 were destroyed.

Seven balloons were prepared from compound A3-130 and submitted for flight testing. These balloons were nominal 1000-gram balloons and were designed to test the flight behavior of Neoprene 400. The balloons were flown with a free lift of 1600 grams, and the flight results are given in Table 144.

A study of these results shows that in spite of the slightly heavier weight and the greater length of these balloons, no substantial improvement in performance was obtained. Although the altitudes reached are satisfactory, the rates of ascent are still below what might be expected from the physical properties of this compound.

* * * * * * *

In order to test the behavior of B.T.N. a series of balloon flights was conducted using balloons manufactured from compound A3-128 with balloons manufactured from compound A3-106 as controls. The only difference between these two compounds is that compound A3-128 contains B.T.N. as a replacement for the N.B.C. used as the antiozonant in A3-106.

All balloons were flown with a free lift of 1600 grams and the weights ranged from 800 to 1000 grams. Results of these flights are recorded in Table 145.

These results show that B.T.N. is apparently suitable as a direct replacement for N.B.C. The average altitude reached by the balloons made from compound A3-128 is somewhat greater than that reached by the balloons made from compound A3-106. However, it should be noted that the majority of the balloons manufactured from compound A3-106 were somewhat shorter than is normally considered acceptable for this type of balloon.

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

TABLE 144

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-130

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-541	K6-4TK	Night	1280	125	107,400	957
EX-3A-542	K7-2TK	Night	1210	118	96,750	951
EX-3A-543	K8-1TK	Day	1180	115	105,300	1095
EX-3A-544	K8-2TK	Day	1240	121	106,600	1074
EX-3A-545	K8-3TK	Day	1260	124	105,700	1052
EX-3A-546	K9-2TK	Night	1240	123	102,400	884
EX-3A-547	K12-2TK	Night	1260	128	112,700	1006

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

TABLE 145

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUNDS A3-106 AND A3-128

Experiment No.	Balloon No.	Compound No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-231	A-1T	A3-106	Day	895	102	96,300	1151
EX-3A-232	A-2T	A3-106	Day	850	100	105,800	1160
EX-3A-233	A-3T	A3-106	Day	875	105	107,900	1116
EX-3A-234	F11-2TK	A3-128	Day	825	93	106,200	1086
EX-3A-235	F12-4TK	A3-128	Day	830	96	106,200	1116
EX-3A-236	F17-3TK	A3-128	Day	805	94	107,000	1104
EX-3A-241	A-4T	A3-106	Day	925	92	102,000	1077
EX-3A-242	A-5T	A3-106	Day	925	90	103,950	1060
EX-3A-243	A-6T	A3-106	Night	920	90	99,400	1042
EX-3A-244	A-7T	A3-106	Night	920	91	101,000	1030
EX-3A-245	A-8T	A3-106	Night	920	92	98,100	1017
EX-3A-246	F11-1TK	A3-128	Night	940	96	111,900	1039
EX-3A-247	F11-3TK	A3-128	Night	860	98	108,200	1040
EX-3A-248	F12-2TK	A3-128	Night	950	98	111,700	988
EX-3A-249	F12-1TK	A3-128	Day	1010	104	108,200	1069
EX-3A-250	F13-1TK	A3-128	Day	920	98	108,500	1046

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

In the same way the rate of ascent of the balloons made from compound A3-128 is somewhat slower that that of the balloons made from compound A3-106. This again is possibly explained by the difference in lengths of the two balloons.

Compound A3-132 showed satisfactory physical properties, and two balloons made from this compound and eight made from the corresponding dual-purpose compound, A3-136, were submitted for flight testing. Balloons made from A3-106 were flown as controls.

Balloons EX-3A-591 and EX-3A-592 were made from compound A3-132, and balloons EX-3A-593 through EX-3A-600 were made from compound A3-136. Balloons EX-3A-601 through EX-3A-606 were made from A3-106 and subjected to eight hours heat aging before flight; balloons EX-3A-607 through EX-3A-612 were standard A3-106 balloons.

The characteristics of these balloons, which were all flown with a free lift of 1600 grams, and their flight performance are given in Table 146.

A study of these flights indicates that compounds A3-132 and A3-136 are equal in performance to A3-106. Furthermore, the good performance of balloons made from A3-106 is confirmed and the flights also indicate that there is no loss in performance after the balloons are subjected to accelerated aging.

A series of flights was next conducted using balloons manufactured from compound A3-129, which contains Butoxy Ethyl Oleate in palce of the Paraflux C-325 used in compound A3-106. In all, eighteen balloons were flown.

Balloons identified as EX-3A-511 through EX-3A-556 were manufactured from compound A3-106, and those identified as EX-3A-491 through EX-3A-496 and EX-3A-641 through EX-3A-646 were manufactured from compound A3-129.

All balloons were flown with a free lift of 1600 grams, and the flight results are given in Table 147.

A study of these results shows that compound A3-129 produces balloons in the 1000-gram range having slightly superior performance to those manufactured from compound A3-106. The rate of ascent of both types of balloons is virtually the same.

FACTUAL DATA (continued)

TABLE 116

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUNDS A3-132, A3-136, A3-106

Experiment No.	Balloon No.	Compound No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-591	M28-1TK	A3-132	Day	810	92	95,240	1023
EX-3A-592	M28-2TK	A3-132	Day	795	90	97,100	1103
EX-3A-593	M28-3TK	A3-136	Night	870	97	95,240	949
EX-3A-594	M28-4TK	A3-136	Night	975	105	72,300	980
EX-3A-595	M28-6TK	A3-136	Night	910	107	110,335	1076
EX-3A-596	M27-1TK	A3-136	Night	940	100	98,000	939
EX-3A-597	M27-4TK	A3-136	Night	965	101	114,829	1041
EX-3A-598	M27-6TK	A3-136	Night	1020	108	100,400	900
EX-3A-599	M26-1TK	A3-136	Night	900	102	110,663	1063
EX-3A-600	M26-2TK	A3-136	Night	940	104	111,352	1047
EX-3A-601	R11-1T	A3-106	Day	1005	100	104,921	1017
EX-3A-602	R11-2T	A3-106	Day	1035	96	96,260	985
EX-3A-603	R11-3T	A3-106	Day	1005	97	84,400	912
EX-3A-604	R11-4T	A3-106	Night	1085	105	116,667	1095
EX-3A-605	R11-5T	A3-106	Night	1010	101	110,007	1055
EX-3A-606	R11-6T	A3-106	Night	1025	99	115,157	1040
EX-3A-607	R24-1T	A3-106	Day	1085	104	77,100	960
EX-3A-608	R24-2T	A3-106	Night	1075	103	103,600	1022
EX-3A-609	R24-3T	A3-106	Day	935	102	110,138	1065
EX-3A-610	R24-4T	A3-106	Night	1000	101	112,956	1075
EX-3A-611	R24-5T	A3-106	Day	1085	103	109,121	1040
EX-3A-612	R24-6T	A3-106	Night	1070	106	101,800	1055

TABLE 147

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUNDS A3-106 AND A3-129

Experiment No.	Balloon No.	Compound No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-551	K16-1T	A3-106	Night	1025	105	99,250	993
EX-3A-552	K16-2T	A3-106	Day	1040	105	98,500	1080
EX-3A-553	K16-3T	A3-106	Night	1040	103	98,740	992
EX-3A-554	K16-4T	A3-106	Day	1030	102	98,800	1027
EX-3A-555	K16-5T	A3-106	Day	1035	103	95,500	1056
EX-3A-556	K16-6T	A3-106	Night	1030	103	97,900	979
EX-3A-491	1T	A3-129	Day	1115	109	103,200	1035
EX-3A-492	2T	A3-129	Night	1090	107	104,200	979
EX-3A-493	3T	A3-129	Day	1095	108	103,800	1045
EX-3A-494	4T	A3-129	Night	1100	104	102,700	1016
EX-3A-495	5T	A3-129	Day	1120	107	105,360	1091
EX-3A-496	6T	A3-129	Night	1105	104	69,100	875
EX-3A-641	S12-1T	A3-129	Night	1055	113	116,690	1051
EX-3A-642	S12-2T	A3-129	Day	1015	112	113,000	1090
EX-3A-643	S12-3T	A3-129	Night	1050	104	81,800	863
EX-3A-644	S12-4T	A3-129	Day	1050	106	102,300	989
EX-3A-645	S12-5T	A3-129	Night	1055	108	111,362	1057
EX-3A-646	S12-6T	A3-129	Day	1020	110	101,000	1039

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

Six balloons made from compound A3-133 were submitted flight testing. This compound employs Dibutyl Sebacate in place of Butyl Oleate because of the difficulties encountered in the making of compounds having high Butyl Oleate content. The gel proved to be difficult to handle, being much softer than similar gels in which Butyl Oleate is the plasticizer. All the balloons tended to be thinner than is considered desirable in the neck area. They were flown with a free lift of 1600 grams, and the characteristics of these balloons together with their flight performance are given in Table 148.

A study of these results shows that the performance is, in general, uniform and surprisingly good considering the appearance of the balloons and their poor low-temperature properties. However, the altitudes are generally low and unsatisfactory. Because of the difficulties of handling this compound in the gel stage, no further work with it is planned.

Six balloons made from compound A3-135 were submitted for flight testing. This compound contains a blend of two accelerators. The balloons were identified as EX-3A-631 through EX-3A-636 and were flown with a free lift of 1600 grams. The characteristics and flight performance are given in Table 149.

A study of these results shows that despite the somewhat shorter length of the balloons, the performance is quite satisfactory and the rates of ascent are unusually high. Additional flights with longer balloons made from this compound appear to be indicated.

Six balloons made from compound A3-137 were submitted for flight testing. This compound contains Mistron Vapor and has a higher modulus than dual-purpose compounds in general. The balloons were identified as EX-3A-651 through EX-3A-656 and were flown with a free lift of 1600 grams. Their characteristics and flight performance are given in Table 150.

A study of these results shows that the balloons performed satisfactorily and that the rate of ascent is substantially above 1000 feet per minute. These results can be anticipated from the physical characteristics of the compound.

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

TABLE 148

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-133

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-621	R21-2TK	Night	880	99	97,960	1026
EX-3A-622	R21-3TK	Night	895	99	98,130	1014
EX-3A-623	R21-4TK	Night	870	101	94,900	954
EX-3A-624	R22-5TK	Day	895	105	97,100*	1004
EX-3A-625	R22-6TK	Day	905	105	97,960	1008
EX-3A-626	R22-8TK	Day	865	98	103,600	1063

*Top Intelligible Data

TABLE 149

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-135

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-631	S21-2TK	Night	1070	98	96,200*	1006
EX-3A-632	S21-4TK	Day	1180	99	88,400	1130
EX-3A-633	S22-2TK	Day	1115	94	99,060	1075
EX-3A-634	S22-3TK	Night	1110	97	110,600	1134
EX-3A-635	S22-5TK	Night	1085	98	110,050	1110
EX-3A-636	S22-7TK	Day	1160	105	battery	failure

*Top Intelligible Data

Balloons in the 1000-gram class and in the 700-gram class were made from compound A3-138. This compound, which is similar to A3-104, was developed in the course of the accelerator study and has somewhat better low-temperature characteristics than does A3-104. Although the elongation at -70°C is not substantially superior, compound A3-138 appears to be much less susceptible to cold flow at this temperature and should, therefore, provide a more reliable balloon than compound A3-104.

Six balloons in the 1000-gram class were submitted for flight testing. They were identified as EX-3A-661 through EX-3A-666 and were flown with a free lift of 1600 grams. Five balloons in the 700 gram class were submitted. They were identified as EX-3A-111 through EX-3A-115 and were flown with a free lift of 1400 grams. The physical characteristics of these balloons and their flight performance are given in Table 151.

A study of these results shows that compound A3-138 provides a reliable dual-purpose balloon capable of reaching 100,000 feet by day or by night. Two 1000-gram balloons (EX-3A-662 and EX-3A-666) which were, respectively, 108 inches and 110 inches in length and were the two longest balloons reached substantially higher altitudes than the remaining four in their weight class which were 102 inches to 103 inches long.

Therefore, it can be stated that balloons made from this compound and intended to reach altitudes of 100,000 feet should be at least 105 inches long when weighing 1000 grams. The rate of ascent of all 1000-gram balloons listed in Table 151 was in excess of 1000 feet per minute.

The performance of the 700-gram balloons is equally satisfactory with the exception of balloon EX-3A-112 which reached an altitude of only 55,000 feet at night. However, other balloons flown on the same night also burst at approximately 50,000 feet (See Table 218, Task C, Phase 3 of this report). It is therefore, strongly evident that unusually low temperatures were encountered on this particular night and that the three balloons in question all froze.

A further six balloons weighing approximately 1750 grams manufactured from compound A3-106 were submitted for flight testing at this time.

TABLE 150

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-137

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-651	T5-1TK	Night	1350	108	111,385	1077
EX-3A-652	T5-2TK	Night	1225	110	102,800	1073
EX-3A-653	T5-3TK	Night	1220	109	109,252	1040
EX-3A-654	T5-4TK	Day	1170	110	Radiosonde Failure	
EX-3A-655	T6-1TK	Day	1170	112	103,300	1097
EX-3A-656	T6-2TK	Day	1180	114	98,200	1001

TABLE 151

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-138

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-661	Y1-1TK	Night	1030	103	100,400	1019
EX-3A-662	Y4-3TK	Night	1070	108	108,200	1028
EX-3A-663	Y5-3TK	Day	1070	102	98,800	1081
EX-3A-664	Y5-4TK	Day	1010	102	102,200	1139
EX-3A-665	Y6-3TK	Night	1100	102	101,700	1025
EX-3A-666	Y6-4TK	Day	1000	110	114,272	1150
EX-3A-111	Y12-4TK	Night	740	97	102,600	1106
EX-3A-112	Y13-1TK	Night	700	78	55,200	962
EX-3A-113	Y13-2TK	Day	700	92	85,000	1022
EX-3A-114	Y13-4TK	Night	660	84	87,200	1015
EX-3A-115	Y14-2TK	Day	670	82	94,840	1089

TASK A, Phase 4, Part B (continued)

This compound has given balloons with satisfactory performance at the 100,000-foot level, and balloons weighing approximately 2250 grams have performed fairly well at 120,000 feet. It was felt, therefore, that a 1750-gram balloon should reach altitudes in excess of 110,000 feet although previous flights with such a balloon had been erratic.

These balloons were identified as EX-3A-1381 through EX-3A-1386 and were flown with a free lift of 1600 grams. Their characteristics and flight performance are given in Table 152.

A study of this table shows that four of the six balloons did, in fact, reach altitudes in excess of 110,000 feet.

The rates of ascent were generally rather slow, which is characteristic of large balloons made from this compound. However, three balloons did have ascensional rates greater than 1000 feet per minute; and balloon EX-3A-1385 which was very slow at an altitude of 54,200 feet, must be considered as defective and should not be included in the evaluation.

Additional flight testing was conducted with balloons made from compound A3-138. Balloons in the 700-gram class, the 1000-gram class and the 1500-gram class were flown, and the flight results are recorded in Table 153, 154 and 155.

Twelve balloons in the 700-gram class were flown. Six of these ranged in length from 102 inches to 109 inches and are identified as EX-3A-121 through EX-3A-126. The remaining six balloons ranged in length from 70 inches to 77 inches and are identified as EX-3A-131 through EX-3A-136. All balloons were flown with a free lift of 1400 grams, and their physical characteristics and flight performance are recorded in Table 153.

A study of these flights shows that the previously recorded performance of compound A3-138 at this level is confirmed. As was expected, the group having the greater length reached substantially higher altitudes but ascended much more slowly.

TABLE 152

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-106

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-1381	T27-1	Night	1760	148	118,965	1016
EX-3A-1382	T27-2	Night	1805	148	119,125	955
EX-3A-1383	T27-3	Day	1810	149	118,340	1057
EX-3A-1384	W1-6	Night	1820	148	111,530	857
EX-3A-1385	W1-7	Day	1775	147	54,200	860
EX-3A-1386	W2-3	Day	1755	147	104,500	1028

TABLE 153

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-138

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-121	C2-1T	Night	735	103	35,800	925
EX-3A-122	C2-2T	Night	705	105	113,914	914
EX-3A-123	C2-3T	Night	685	102	100,200	881
EX-3A-124	C2-4T	Day	735	105	90,500	938
EX-3A-125	C2-5T	Day	730	107	89,200	955
EX-3A-126	C2-6T	Day	750	109	93,200*	987
EX-3A-131	C20-1T	Day	735	75	87,500	1241
EX-3A-132	C20-2T	Night	735	74	85,800	966
EX-3A-133	C20-3T	Day	730	70	83,400	1132
EX-3A-134	C20-4T	Night	725	74	81,400	981
EX-3A-135	C20-5T	Night	720	75	84,700	953
EX-3A-136	C20-6T	Day	785	77	88,500	1062

*Top intelligible data

TASK A, Phase 4, Part B (continued)

The rate of ascent of the shorter balloons in the daytime is completely satisfactory, but at night it is somewhat inadequate. This is a bit surprising in view of the relatively high modulus of this compound. However, the study of the effect of modulus on shape during inflation which is reported in Task B, Phase E, of this report, throws some light on this apparently anomalous behavior.

Ten balloons in the 1000-gram range manufactured from compound A3-138 were also flown. These balloons were identified as EX-3A-681 through EX-3A-684 and EX-3A-690 through EX-3A-695, and they were all flown with a free lift of 1600 grams. The results of these flights are recorded in Table 154.

A study of these results shows that the performance is satisfactory. Eight of the ten balloons reached altitudes in excess of 100,000 feet. The rate of ascent at night is still somewaht border line, however, two of the five flights failing to ascend at more than 1000 feet per minute.

Six balloons in the 1500-gram class made from compound A3-138 were also submitted for flight testing. These balloons are identified as EX-3A-1391 through EX-3A-1396 and were flown with a free lift of 1600 grams. The characteristics of these balloons and their flight performance are recorded in Table 155.

The results of these flights are extremely disappointing. It would appear that even in the daytime, it is necessary for these balloons to be slightly elongated before low temperatures are reached if the potential elongation is to be obtained during flight.

Six balloons made from compound A3-138 which had been shelf aged for six months were flown. These balloons were identified as EX-3A-701 through EX-3A-706. They were flown with a free lift of 1600 grams, and their physical characteristics and flight performances are recorded in Table 156.

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

TABLE 154

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-138

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-681	B23-1T	Night	1070	100	102,000	919
EX-3A-682	B23-2T	Night	1065	102	112,467	933
EX-3A-683	B23-3T	Day	1090	108	110,663	1080
EX-3A-684	B23-4T	Day	1070	105	83,100	1039
EX-3A-690	B28-1AM	Night	1065	109	104,700	1000
EX-3A-691	B28-2AM	Day	1070	106	113,156	1158
EX-3A-692	C2-1AM	Day	1045	102	93,200	1055
EX-3A-693	C2-2AM	Day	1110	102	105,000	1127
EX-3A-694	C2-6AM	Night	1060	101	101,400	1024
EX-3A-695	C6-3AM	Night	1050	103	100,500	1041

TABLE 155

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-138

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-1391	A22-4AM	Day	1610	135	82,150	978
EX-3A-1392	A23-1AM	Night	1565	135	80,800	921
EX-3A-1393	A25-3AM	Night	1590	128	77,800	987
EX-3A-1394	A26-1AM	Night	1605	129	80,800	983
EX-3A-1395	A26-2AM	Day	1600	128	100,300	967
EX-3A-1396	A26-3AM	Day	1570	129	109,482	1138

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

A study of these results shows that the performance of these balloons after aging for six months is satisfactory. Five of the six flights reached altitudes in excess of 100,000 feet and the one that failed to reach this altitude did so by only 2550 feet.

The rates of ascent were greater than 1000 feet per minute in four of the six flights, and the lowest rate of ascent was exhibited by the balloon which reached the lowest altitude, which is a normal condition.

A group of six balloons desinged for flight in the Tropical Zone was also submitted for flight testing. These balloons were identified as EX-3A-721 through EX-3A-726.

Balloons EX-3A-721 through EX-3A-723 were made from compound A3-106 modified to increase the plasticizer content to 40 parts. Balloons EX-3A-724 through EX-3A-726 were made from compound A3-138 with the plasticizer content increased to the same level.

Both compounds were checked at -78°C which is the minimum temperature attainable by the cold box, and neither film froze. Both had elongations of more than 500%, the modified A3-106 film having better elongation and lower modulus than the modified A3-138 film.

The balloons were in the 1200-gram class, and were all flown at night with a free lift of 1600 grams. Their characteristics and flight performance are given in Table 157.

A study of the results in Table 157 shows that all balloons did quite well both in altitude and ascensional rate. The first group, EX-3A-721 through EX-3A-723, were somewhat superior.

Arrangements were, therefore, made to fly similar balloons at night in the Tropical Zone. Ten balloons made from compound A3-138 with the high plasticizer level were submitted for tests and seven flights were completed, the balloons being released at sunset. The characteristics of these balloons and their flight performance are given in Table 158.

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

TABLE 156

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-138

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-701	F2-3AM	Night	1175	109	110,433	1025
EX-3A-702	F9-4AM	Night	1195	110	113,123	1003
EX-3A-703	F10-1AM	Night	1195	110	113,747	973
EX-3A-704	F10-2AM	Day	1215	110	105,052	1087
EX-3A-705	F10-3AM	Day	1170	109	106,102	1060
EX-3A-706	F10-4AM	Day	1190	112	97,450	946

TABLE 157

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUNDS A3-106 AND A3-138 MODIFIED FOR TROPICAL ZONE USE

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-721	M11-1T	Night	1275	114	118,000	1098
EX-3A-722	M11-2T	Night	1365	114	113,400	1070
EX-3A-723	M11-3T	Night	1340	115	112,336	1179
EX-3A-724	M11-4TM	Night	1265	113	111,319	1126
EX-3A-725	M11-5TM	Night	1355	102	91,090*	999
EX-3A-726	M11-6TM	Night	1275	112	104,750	1111

* Hole in balloon tied off.

FACTUAL DATA (continued)

TASK A, Phase 4, Part B (continued)

A study of these results shows that, as was anticipated these balloons will perform satisfactorily during the Tropical night. Disregarding balloon EX-3A-804, five out of the remaining six reached altitudes in excess of 100,000 feet and all the balloons rose at rates in excess of 1000 feet per minute. Since it has already been shown that the balloon will perform satisfactorily in the Temperate Zone it may be concluded that it is now possible to produce a balloon capable of reaching an altitude of 100,000 feet when flown by night in any geographical location.

Neoprene 673 when incorporated into compound 2A-16 showed very interesting physical properties, particularly insofar as high modulus was concerned. This compound was therefore, assigned the number A3-165 and balloons were prepared for flight testing. These balloons were identified as EX-3A-761 through EX-3A-765 and their physical characteristics and flight performance are given in Table 159.

These results are extremely disappointing, both as far as altitudes and ascensional rates are concerned. The physical properties of this compound indicate that altitudes of 100,000 feet should be attainable and the high modulus suggests that these balloons should have a high rate of ascent, neither of which results have been achieved.

In order to find an explanation for this anomalous behavior a group of 100-gram balloons were prepared and cured in the same manner as the 1000-gram balloons. It has previously been pointed out that the film has to age and be allowed to crystallize if the high modulus is to be developed. Accordingly, the 100-gram balloons were retained for seven days before any tests were carried out.

Physical tests on the balloon film demonstrated that crystallization has occured after this interval and three of the 100-gram balloons were now slowly inflated to burst. It was observed that although the balloon is initially perfectly round, a yield point is reached at which one section of the balloon continues to expand and the remaining portion remains at the same elongation. As the inflation is continued the expansion remains confined to the area which originally began to stretch and the balloon finally ruptures with the greater

FACTUAL DATA (continued)

TABLE 158

FLIGHT RESULTS - BALLOONS MADE FROM COMPOUND A3-138 WITH ADDITIONAL PLASTICIZER AS FLOWN AT PANAMA

Experiment No.	Balloon No.	Weight (grams)	Length (inches)	Minimum Temperature (°C.)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-801	A16-1	1285	115	-79.2	116,850	1060
EX-3A-802	A16-5	1305	114	-76.7	86,437	1004
EX-3A-803	A9-1	1270	114	-74.1	116,480	1027
EX-3A-804	A17-3	1320	112	-76.6	63,051*	961
EX-3A-805	A16-4	1315	113	-78.5	104,088	1009
EX-3A-806	A9-4	1295	112	-76.1	112,454	1050
EX-3A-807	A17-1	1305	115	-75.9	103,596	1056

*Top intelligible data

TABLE 159

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-165

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-761	R28-2TJ	Day	940	99	Radiosonde Failure	
EX-3A-762	R28-3TJ	Day	1045	107	68,000	1091
EX-3A-763	R28-4TJ	Day	1000	108	79,710	1084
EX-3A-764	R28-5TJ	Night	945	108	41,300	1291
EX-3A-765	R28-6TJ	Night	1005	102	47,800	1226

part of the balloon never having stretched beyond the point of the initial small expansion. This, of course, results in very low bursting volumes and also in badly mis-shapen balloons. This, then, explains both the low altitudes reached and the relatively slow ascensional rates.

A further series of laboratory tests on dumb-bell samples showed that the condition which is encountered when testing at low temperatures, which is described as cold flow, exists very markedly at room temperature with this compound. These tests, thus far conducted, were largely qualitative and the whole area of the behavior of highly crystallized polymers requires careful investigation. The preliminary results seem to indicate that this type of polymer is not suitable for use in meteorological balloons.

Part C: Fast-Rise Balloons

Fast-rise, spherical balloons are still used despite the excessive amount of gas required to produce the necessary rate of ascent. Two-piece, streamlined balloons and balloons having shapes other than spherical achieve much higher rates of ascent with considerably less free lift (see Task C).

However, the spherical balloon is still the most reliable fast-rise balloon and is useful as a means of screening fast-rise compounds until such time as two-piece or otherwise streamlined balloons are standardized, and their performance characteristics better understood.

Accordingly, four balloons made from compound A3-3, which was developed under Contract DA-36-039-SC-78239 and which is now numbered A3-102, were submitted for flight testing. They weighed approximately 2250 grams and were all flown with a free lift of 7000 grams during the hours of daylight. The balloons were identified as EX-71 through EX-74. Characteristics and flight performance are given in Table 160.

Analysis of these results shows that the rates of ascent are inferior to those of similar balloons flown during Contract DA-36-039-SC-78239. These balloons, although of about the same length, were approximately 500 grams heavier than balloons EX-71 through EX-74.

FACTUAL DATA (continued)

TASK A, Phase 4, Part C (continued)

It may be concluded, therefore, that the reduction in film thickness is responsible for the reduction in performance.

Further work with this compound is reported in Task C, Phase 2.

A fast-rising balloon compound was developed during this contract and identified as A3-134. Two-piece, streamlined balloons made from this compound were moderately successful, and it was decided to fly one-piece balloons made from this same compound.

These one-piece balloons which weighed approximately 3300 grams were identified as EX-3A-3001 through EX-3A-3004 and were flown with a free lift of 7000 grams. Characteristics of these balloons and their flight data are given in Table 161.

A study of these results shows that, although the altitudes attained are fairly satisfactory, ranging from 75,000 feet to 95,000 feet, the rates of ascent are below what was hoped for. In a somewhat unusual reversal of normal performance, the night-flight balloons ascended more rapidly than either of the day-flight balloons. This may be an indication that the modulus of the compound in the daytime is lower than is desirable for this type of balloon.

Two further groups of thick-walled balloons were also submitted for flight testing. Six of these balloons were manufactured from compound A3-138, and these were identified as EX-23-301 through EX-2C-306. The remaining six were manufactured from compound A3-106, and these were identified as EX-2C-311 through EX-2C-316.

The latter group was, in general, somewhat shorter and a little heavier than the first group; however, all balloons were flown with a free lift of 2500 grams. Their characteristics and flight performance are given in Table 162.

A study of these results shows that the first group, manufactured from compound A3-138, reached higher altitude as was to be expected due to their greater length. The balloons made from compound A3-106, however, showed much higher rates of ascent. It is possible that these balloons did so because of the fact that a much better shape is maintained through the flight. (See Task B, Phase E, of this report.) There is, otherwise, insufficient difference in the normally-recorded physical properties to explain this large difference in rate of ascent.

TABLE 160

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-102

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Flaccid Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-71	B3-1	Day	2275	122	105,800	1645
EX-72	B3-3	Day	2275	124	106,300	1640
EX-73	B3-5	Day	2375	125	69,500	1517
EX-74	B4-3	Day	2275	122	82,000	1577

TABLE 161

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-134

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-3001	W6-3AM	Night	3325	137	95,500	1661
EX-3A-3002	W7-2AM	Day	3165	135	74,520	1595
EX-3A-3003	W8-2AM	Day	3345	134	87,600	1406
EX-3A-3004	W13-3AM	Night	3445	126	82,500	1608

TABLE 162

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUNDS A3-138 AND A3-106

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-2C-301	A31-1AM	Night	955	69	74,900	1159
EX-2C-302	A31-3AM	Night	920	68	82,650	1088
EX-2C-303	A31-5AM	Day	930	68	86,450	1209
EX-2C-304	B8-2AM	Day	940	70	86,650	1150
EX-2C-305	B8-5AM	Day	980	70	93,950	1219
EX-2C-306	B9-2AM	Night	995	70	84,200	1188
EX-2C-311	C12-5AM	Day	1080	60	54,700	1474
EX-2C-312	C13-2AM	Night	1095	66	67,800	1427
EX-2C-313	C14-2AM	Day	1080	62	70,700	1429
EX-2C-314	C14-3AM	Night	1080	61	60,900	1318
EX-2C-315	C14-4AM	Night	1080	60	59,500	1634
EX-2C-316	C15-5AM	Day	1070	60	58,000	1611

FACTUAL DATA (continued)

TASK B: EFFECT OF FLIGHT CONDITIONS ON BALLOON FILM PERFORMANCE

Phase 1: Effect of Pre-elongation

The means of increasing the elongation of balloon films by pre-elongation before reducing the temperature has been well established. It has, however, never proved practical to take advantage of this phenomenon to increase bursting altitudes of large balloons.

Pre-elongation at room temperature, as might be expected, has no effect on the room-temperature elongation, and elongation of the film at room temperature followed by relaxation of the film and subsequent reduction in temperature is ineffective as a menas of increasing low-temperature elongation.

Balloons made from two compounds -- A3-105, a day-flight compound, and A3-106, a dual-purpose compound--were evaluated at -40°C and -70°C, respectively. Samples of the dual-purpose compound were tested at both temperatures without being pre-elongated and after having been pre-elongated 100% before the temperature was reduced. The samples of compound A3-106 were tested at -40°C with and without pre-elongation. The results of these tests are given in Table 163.

A study of these results affords an interesting insight into the behavior of meteorological balloons. If the physical characteristics of the balloon film before pre-elongation are considered, it can be seen that the day-flight compound, A3-105, has an elongation at -40°C of 620%, whereas the dual-purpose compound, A3-106, has an elongation of 760%.

It would, therefore, be reasonable to assume that a balloon made from a dual-purpose compound should reach a substantially higher altitude in the daytime than a balloon of the same weight and length made from a day-flight compound.

This, however, is not the case. In fact, dual-purpose balloons reach approximately the same altitude in the daytime as do similar balloons made from a day-flight compound. Furthermore, dual-purpose balloons reach the same altitude by day and by night; whereas, on the basis of their elongations at -40°C and -70°C, they might be expected to reach higher altitudes in the daytime.

The above results afford a clear explanation of the anomalies. A dual-purpose balloon flown at night is already extended at least 100% (in the case of a balloon designed to reach an altitude of 100,000 feet) before it reaches the minimum temperature levels. Consequently, it is capable of achieving a breaking elongation of about 700%. The same balloon when flown in the daytime and when the minimum temperature of the balloon is only about -40°C has only a very slightly greater elongation whether or not it is pre-elongated.

FACTUAL DATA (continued)

TASK B, Phase 1 (continued)

TABLE 163

EFFECT OF PRE-ELONGATION ON BALLOONS MADE FROM COMPOUNDS A3-105 AND A3-106 TESTED AT -40°C. AND AT -70°C.

Compound No.	Test Temp. (°C.)	Pre-Elongation (%)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A3-105	-40	none	580	1330	2665	4220	620
	-40	100	240	500	1080	2690	760
A3-106	-40	none	155	315	780	1560	760
	-40	100	150	225	600	1490	770
A3-106	-70	none	1700	2770	-	4075	510
	-70	100	550	775	2100	2885	690

FACTUAL DATA (continued)

TASK B, Phase 1 (continued)

The day-flight balloon which has a normal elongation at -40°C of 620% can also achieve an elongation of 700% or better if it is pre-elongated. Hence, under the three sets of conditions described, all the balloons are capable of reaching the same breaking elongation and, therefore, may be expected to reach the same altitude which is, in fact, exactly what they do.

Therefore, a further test for use in the prediction of balloon flight performance has been obtained.

Phase 2: Effect of Ozone

The following report was received from Dr. Julius London:

The Vertical Distribution of Ozone

The characteristic distribution of ozone in the atmosphere is such that it increases upward from the ground where the surface values are approximately $1:10^8$ to a maximum concentration at about 25 km. Here the concentration is approximately 17×10^{-3} cm(STP)/km. Above 25 km the ozone concentration decreases rapidly. The seasonal variation of the vertical ozone distribution is not very large and is confined mainly to the regions below 25 km where because of the long half life and vigorous atmospheric circulation, the winter values are somewhat larger than those found during the summer.

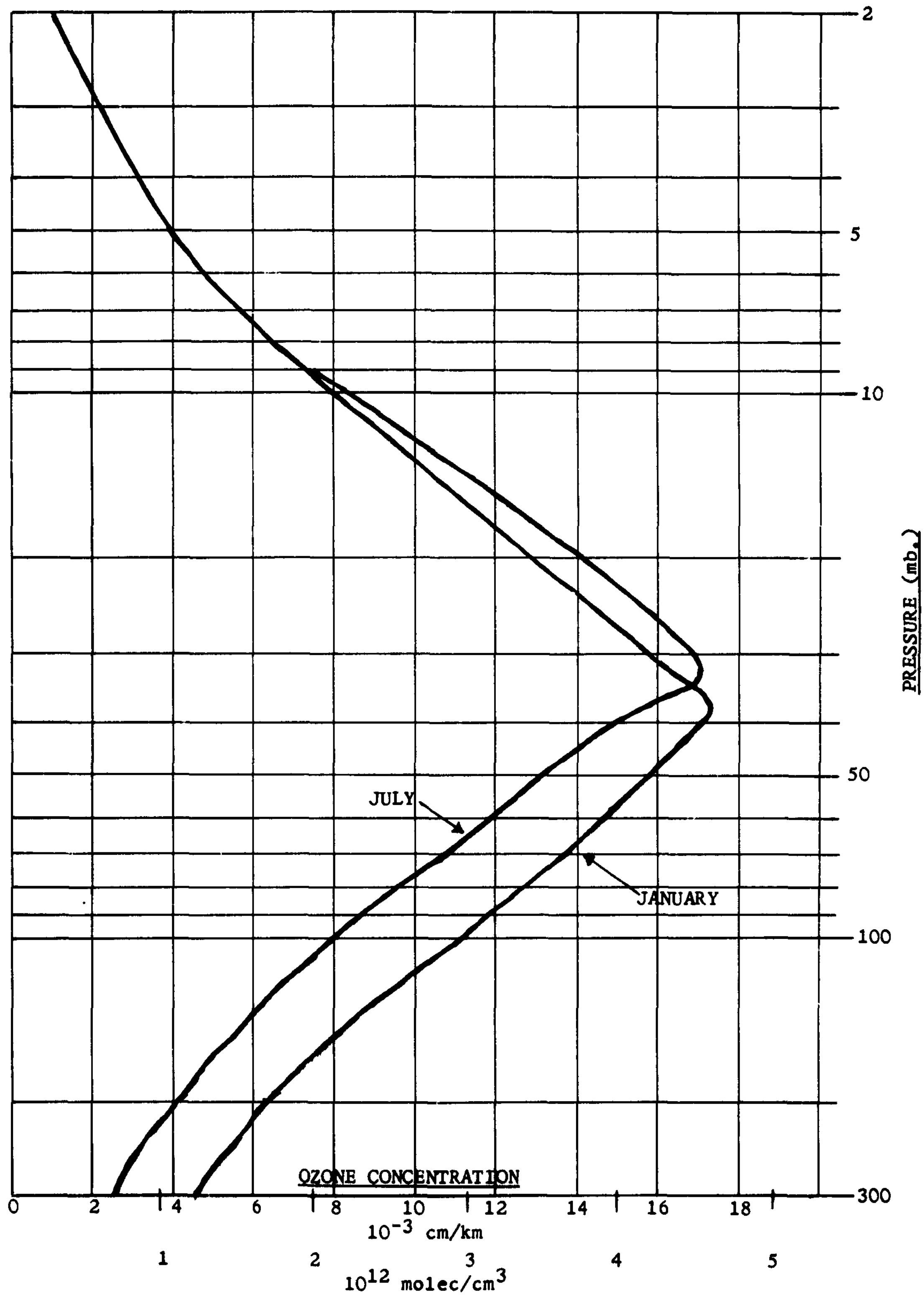
Figure 1 shows typical vertical variations for both winter and summer as found at latitude 55° N. These values represent a probable maximum concentration. The abscissa is plotted in units of 10^{-3} cm(STP)/km and 10^{12} molecules/cm^3.

* * * * * *

An ozonator was purchased so that ozone tests could be carried out in our own laboratories. This unit is model B-2 manufactured by G. F. Bush associates of Hopewell, New Jersey. The instrument is designed to provide accurately controlled ozone concentration of from 5,000 to 15,000 parts per hundred million. It is also equipped with means for reducing the concentration to the more normal operating figure of 150 parts per hundred million.

FIGURE 1

AVERAGE OZONE CONCENTRATION AT VARYING ALTITUDES AT 55°N



FACTUAL DATA (continued)

TASK B. Phase 2 (continued)

The unit is self-contained with flow meters for operation and sampling. Concentration is determined by outside titration after the ozonized air has been sampled in the unit. The chamber is cylindrical, twelve inches in diameter and fifteen inches in height, with a capacity of one cubic foot. Means for heating the chamber are provided.

The ozonator was calibrated and operates satisfactorily. The ozone concentration is determined according to the following procedure:

> Ten grams of potassium iodide are dissolved in a mixture of 30 cc of 0.025N disodium hydrogen phosphate and 20 cc of 0.025N potassium dihydrogen phosphate. The ozonator is started; and after allowing sufficient time for conditions to stabilize, the sampling valve is opened and ozonized air passed through the above solution for two minutes. The liberated iodine is titrated with sodium thiosulphate using a starch indicator.
>
> The ozone concentration is calculated from the formula:

$$\text{Ozone Conc.} = \frac{\dfrac{11.2\ (\text{molarity of sodium thiosulphate})}{(\text{No. ccs sodium thiosulphate})\ 10^2}}{\text{Flow rate (cc/min)} \times \text{Time (in mins)}}$$

> Good reproducibility of results was obtained, and the ozonator was set to maintain an ozone concentration of 80 parts per million.

Previous tests on ozone resistance performed at 200% and 600% elongation indicated that the rate of attack was greater at the lower than at the higher elongation. This contradicts the generally accepted behavior of neoprene on exposure to ozone. However, since the flight performance of larger balloons is generally much more erratic, and since these are much less stretched when they enter the layer of maximum ozone concentration, it was decided to pursue this line of investigation in greater detail.

Samples made from compound A3-106 were stretched to 50%, 100%, 150%, and 200% and placed in the ozone chamber. This is a dual-purpose compound and was selected because it was already known that high-plasticizer-content compounds are subject to more rapid attack than are compounds with low-plasticizer content.

FACTUAL DATA (continued)

TASK B, Phase 2 (continued)

The samples were observed throughout the test and their condition noted at five-minute intervals. Two sets of samples were evaluated in this way, and the results are given in Table 164.

Although these results do not indicate a clear pattern, there is strong evidence that the rate of attack is greatest at 50% elongation. A further three sets of samples were tested according to the same procedure, and the results of these tests are given in Table 165.

A study of these results shows that a much clearer pattern has been established. In all cases, the samples stretched 50% and 100% show earlier signs of attack and break before the samples stretched 150% and 200%. It would, therefore, appear that larger balloons which are less expanded at the layer of maximum ozone concentration are much more susceptible to attack by ozone than are smaller balloons. It can, however, be argued that balloons are not exposed to ozone concentrations such as have been used in these tests (8,000 parts per hundred million) and that the length of time of exposure during a flight is relatively short. Nevertheless, even relatively short exposure and comparatively minor attack may have a marked effect on the ultimate elongation of the film.

A set of samples was, therefore, stretched to elongations of 50%, 200%, 400%, and 600% and placed in the ozone chamber for 15 minutes, the ozone concentration being reduced to approximately 4,000 parts per hundred million. After exposure, the elongation of the samples was determined on the Scott Tester. The results were as follows:

Initial Elongation		Ultimate Elongation *
50%	(visible attack)	650%
200%	(visible attack)	720%
400%	(slight attack)	830%
600%	(no visible attack)	830%

* After exposure

These results also point in the same direction; and it was, therefore, decided to undertake a comprehensive study of the ozone resistance of different types of balloon compounds at low elongations since this may afford an aswer to the erratic performance of large balloons designed to reach altitudes much in excess of 100,000 feet.

TABLE 164

OZONE ATTACK ON SAMPLES FROM A3-106 AT VARIOUS ELONGATIONS

Elongation	Exposure time in minutes											
	5	10	15	20	25	30	35	40	45	50	55	60
50%	N	N	S	H	H	Broke						
100%	N	N	S	H	H	Broke						
150%	N	N	S	C	C	H	H	H	H	H	H	H
200%	N	N	S	C	C	H	H	Broke				
50%	N	S	H	Broke								
100%	N	N	N	S	S	S	C	H	Broke			
150%	N	N	S	C	H	Broke						
200%	N	N	S	S	S	S	C	C	H			

TABLE 165

OZONE ATTACK ON SAMPLES FROM A3-106 AT VARIOUS ELONGATIONS

Elongation	Exposure time in minutes											
	5	10	15	20	25	30	35	40	45	50	55	60
50%	N	S	H	Broke								
100%	N	S	H	Broke								
150%	N	N	S	H	Broke							
200%	N	N	S	H	Broke							
50%	N	N	S	H	H	Broke						
100%	N	N	S	C	H	H	H	Broke				
150%	N	N	N	S	C	C	C	H	H	Broke		
200%	N	N	N	S	C	C	C	H	H	Broke		
50%	N	S	C	H	H	Broke						
100%	N	S	C	H	H	Broke						
150%	N	S	S	C	C	H	H	H	Broke			
200%	N	S	S	C	C	H	H	H	Broke			

N No attack
S Slight attack
C Considerable attack
H Heavy attack

FACTUAL DATA (continued)

TASK B, Phase 2 (continued)

To be sure that all tests were conducted under comparable conditions, the ozonator was carefully recaliberated and the ozone concentration was adjusted to .005%.

The method of test employed consisted of placing four dumbbell test pieces in a rack, the four test pieces being spaced equidistantly around the chamber. Each test piece could be elongated to any desired degree up to 600% prior to introduction into the chamber.

In order to be sure that the location of the test piece did not influence the results and that the ozone concentration was uniform throughout the test chamber, sixteen dumbells were cut from a balloon made from compound A3-105. These were stretched to 600%, removed from the chamber after twenty minutes exposure, and the breaking elongation then determined. The results of these tests are given in Table 166.

A study of these results indicates that the location of the test piece in the chamber has little or no influence. However, it was still considered desirable to eliminate this possible source of error, and tests were generally conducted so that any given elongation was not always located in the same position in the test chamber.

Dumbbell samples were next cut from a balloon made from compound A3-105, and four samples were stretched, respectively, to 25%, 50%, 100% and 200% elongation, placed in the test chamber, and the test was conducted until at least three of the samples had broken. This test was repeated three times, changing the position of the samples in the test chamber. The results are given in Table 167.

A similar set of tests was conducted with samples stretched to 50%, 200%, 400% and 600%, and their results are reported in Table 168.

A study of these results shows clearly that the rate of attack increases as the elongation increases. It should be noted that the last group of tests in Table 167 and the first group in Table 168 were conducted with dumbbells cut from experimental films and not from balloons, although the compound is the same throughout.

The samples obtained from the experimental films were not subjected to a gel expansion process such as is the case for meteorological balloons. The experimental films have a considerably longer life in the ozone chamber, so it is clear that ozone resistance tests must be conducted on samples cut

TABLE 166

OZONE TESTS ON DUMBBELL SAMPLES CUT FROM COMPOUND A3-105 TO DETERMINE RATE OF ATTACK AT VARIOUS POSITIONS IN CHAMBER

Test No.	Position No. 1		Position No. 2		Position No. 3		Position No. 4	
	Appear-ance	Elongation after Test	Appear-ance	Elongation after Test	Appear-ance	Elongation after Test	Appear-ance	Elongation after Test
1	S	870	S	820	S	840	S	870
2	S	780	S	810	S	810	S	800
3	S	840	S	820	S	840	S	820
4	S	810	S	820	S	840	S	820

S Slight attack

FACTUAL DATA (continued)

TASK B. Phase 2 (continued)

TABLE 167

OZONE ATTACK ON DUMBBELL SAMPLES CUT FROM COMPOUND A3-105 AT VARIOUS ELONGATIONS

Position in Chamber	Elongation (%)	Exposure time in minutes								
		10	25	35	40	45	60	120	150	180
1	25	N	N	N	N	N	VS	VS	VS	VS
2	50	N	N	N	VS	S	C	Broke		
3	100	N	S	C	H	Broke				
4	200	N	S	H	Broke					
1	200	N	S	H	H	Broke				
2	100	N	S	C	C	Broke				
3	50	N	VS	VS	S	C	C	Broke		
4	25	N	N	VS	VS	VS	VS	VS	VS	VS
1	25	N	N	N	N	N	N	VS	VS	VS
2	50	N	N	N	VS	VS	VS	C	C	Broke
3	100	N	N	VS	VS	VS	S	C	Broke	
4	200	N	N	VS	VS	VS	S	Broke		

N = No attack
VS = Very slight attack
S = Slight attack
C = Considerable attack
H = Heavy attack

FACTUAL DATA (continued)

TASK B, Phase 2 (continued)

TABLE 168

OZONE ATTACK AT VARIOUS ELONGATIONS ON DUMBBELL SAMPLES FROM A3-105

Position in Chamber	Elongation (%)	Exposure time in minutes							
		15	25	40	60	80	100	120	150
1	50	N	N	N	N	N	N	N	VS
2	200	N	N	VS	VS	VS	VS	VS	Broke
3	400	VS	VS	S	S	S	C	H	Broke
4	600	VS	VS	S	C	H	H	Broke	
1	600	Broke							
2	400	C	C	C	Broke				
3	200	S	S	C	H	Broke			
4	50	S	S	S	C	H	H	Broke	
1	600	H	H	Broke					
2	400	H	H	H	Broke				
3	200	S	S	C	H	H	Broke		
4	50	N	N	VS	VS	S	S	Broke	

N = No attack
VS = Very slight attack
S = Slight attack
C = Considerable attack
H = Heavy attack

FACTUAL DATA (continued)

TASK B, Phase 2 (continued)

from actual balloons, otherwise the results obtained are likely to be misleading, indicating that the compound has considerably better ozone resistance than is actually the case for the balloon itself.

It is, nevertheless, interesting to note that whether or not the film is derived from an expanded gel, the rate of attack is still greater at higher elongations. This is contrary to the previous findings already reported. However, the previous results were obtained using films obtained from balloons manufactured from compound A3-106, which has a much higher plasticizer content than A3-105.

Tests were, therefore, conducted on films made from compound A3-106, using samples elongated 25%, 50%, 100%, and 200% in the first series; 50%, 200%, 400%, and 600% in the second series; and 200%, 300%, 400%, and 500% as well as 25%, 50%, 200%, and 600% in the third series. Results of these tests are given in Tables 169, 170 and 171.

A study of these tables shows that the original findings using films made from compound A3-106 are confirmed. The rate of attack is greater at low elongations than at higher elongations.

On the basis of the results so far obtained, it would appear that a day-flight balloon, that is, one made from a compound with a relatively low plasticizer content and designed to reach an altitude of 100,000 feet, would be liable to lose only relatively little altitude if exposed to ozone concentrations sufficient to cause degradation of the film.

The maximum atmospheric ozone concentration is normally encountered at altitudes of approximately 90,000 feet. Such a balloon at this altitude would be extended almost to its breaking elongation where the rate of attack is at its greatest. However, since it is also close to its theoretical bursting altitude, the loss in altitude must be relatively small.

A balloon made from the same compound but designed to reach an altitude of, say,150,000 feet would be less extended when it reached the altitude of maximum ozone concentration. It would, therefore, be better equipped to withstand attack by ozone; but if the concentration were large enough to cause attack, the loss in altitude would, of course, be considerable. However, a reasonable conclusion would be that high-altitude balloons manufactured from day-flight compounds would have good possibilities of passing through the ozone layer without being attacked.

TABLE 169

OZONE ATTACK AT VARIOUS ELONGATIONS ON DUMBBELL SAMPLES FROM A3-106

Position in Chamber	Elongation (%)	Exposure time in minutes						
		6	8	10	12	14	16	18
1	25	N	N	VS	S	S	C	C
2	50	N	S	C	Broke			
3	100	N	VS	S	C	H	Broke	
4	200	N	VS	S	C	C	H	Broke
4	25	N	N	N	N	VS	S	S
1	50	VS	S	C	H	Broke		
2	100	VS	C	H	Broke			
3	200	N	N	N	S	C	H	Broke
2	25	N	N	N	N	N	N	N
4	50	VS	S	Broke				
1	100	N	S	C	H	Broke		
3	200	N	VS	S	C	H	H	Broke
3	25	N	N	S	C	C	C	C
1	50	N	S	C	H	Broke		
4	100	N	S	C	H	H	Broke	
2	200	N	C	H	Broke			
3	25	N	N	N	VS	VS	S	S
2	50	N	S	C	H	Broke		
4	100	N	N	S	C	H	Broke	
1	200	N	S	S	H	H	Broke	

N = No attack
VS = Very slight attack
S = Slight attack
C = Considerable attack
H = Heavy attack

TABLE 170

OZONE ATTACK AT VARIOUS ELONGATIONS ON DUMBBELL SAMPLES FROM A3-106

Position in Chamber	Elongation (%)	Exposure time in minutes						
		6	8	10	12	14	16	18
1	50	N	VS	S	H	Broke		
2	200	N	N	VS	C	H	Broke	
3	400	N	N	N	N	N	N	N
4	600	N	N	N	N	N	N	N
4	50	N	N	S	H	Broke		
3	200	N	S	H	Broke			
2	400	N	N	Broke*				
1	600	N	N	N	N	N	N	N
3	50	N	S	C	H	Broke		
1	200	N	S	C	H	Broke		
4	400	N	N	N	N	N	N	N
2	600	N	N	N	N	N	N	N
2	50	VS	S	C	H	Broke		
4	200	N	N	S	C	C	H	Broke
1	400	N	N	N	Broke*			
3	600	N	N	N	N	N	N	N
3	50	N	S	C	H	Broke		
2	200	VS	C	H	Broke			
4	400	N	N	N	N	N	S	S
1	600	N	N	N	N	N	N	N

* Sample broke at clamps with no evidence of attack between bench marks.

N = No attack
VS = Very slight attack
S = Slight attack
C = Considerable attack
H = Heavy attack

TABLE 171

OZONE ATTACK AT VARIOUS ELONGATIONS ON DUMBBELL SAMPLES FROM A3-106

Position in Chamber	Elongation (%)	Exposure time in minutes						
		6	8	10	12	14	16	18
1	200	S	C	H	Broke			
2	300	S	C	Broke				
3	400	N	N	N	N	N		
4	500	N	N	N	N	N		
4	200	N	VS	S	C	H	Broke	
3	300	N	N	VS	C	H	Broke	
1	400	N	N	N	N	N	N	
2	500	N	N	N	N	N	N	
2	200	N	VS	S	C	Broke		
3	300	N	N	N	VS	C	Broke	
4	400	N	N	N	N	N	N	
1	500	N	N	N	N	N	N	
2	25	N	N	VS	VS	S	C	H
1	50	N	VS	S	C	Broke		
3	200	N	N	S	C	H	Broke	
4	600	N	N	N	N	N	N	N
3	25	N	N	N	VS	C	H	H
4	50	N	VS	C	H	Broke		
1	200	VS	S	H	Broke			
2	600	N	N	N	N	N	N	N

N = No attack
VS = Very slight attack
S = Slight attack
C = Considerable attack
H = Heavy attack

FACTUAL DATA (continued)

TASK B, Phase 2 (continued)

In the case of the dual-purpose balloons which are made from compounds having a high-plasticizer content, a different picture is presented. Since the dual-purpose type of compound shows better resistance to ozone attack at high elongations, balloons designed to reach altitudes of 100,000 feet should do so with greater consistency than day-flight balloons.

The 100,000-foot, dual-purpose when close to its breaking elongation, which it is when it enters the layer of maximum ozone concentration, has greater resistance than when only slightly elongated. It must, however, be borne in mind that the inherent ozone resistance of the high-plasticizer-content compound is lower than that of the low-plasticizer, day-flight compound. Hence, although the day-flight balloon is more susceptible to attack by virtue of its higher elongation, the superior ozone resistance of the compound when compared with a dual-purpose compound could still be sufficient to prevent rupture of the balloon for this reason.

In the case of the high-altitude, dual-purpose balloon designed to reach 150,000 feet, a different situation is again presented. This balloon with its inherent low resistance to ozone passes through the atmospheric layer of maximum ozone concentration when its elongation is low and, therefore, when its susceptibility to attack is at its greatest. It appears necessary, therefore, to provide much greater ozone resistance by the use of antiozonants or similar materials in the case of dual-purpose, high-altitude balloons than would be necessary for a similar day-flight balloon.

The above conclusions have all been based on the results obtained on dumbbell test pieces. However, the unilateral extension of a dumbbell does not duplicate the multilateral extensions to which a balloon is subjected in flight.

Because of the apparently complex nature of ozone attack, it was considered essential to perform a similar series of tests using inflated patches instead of dumbbells. The dumbbell test pieces were originally used since it is possible to conduct four tests simultaneously whereas the use of patches necessitates conducting single tests since the chamber will only hold one such sample at a time.

A series of tests was now conducted using patches cut from a balloon manufactured from compound A3-105. These patches were inflated to 100%, 200%, 400%, and 600% elongation. They were visually observed as were the dumbbell test pieces, but it was not possible to measure the extent of the attack because as soon as any attack became apparent the sample either broke or deflated. In fact, rupture or deflation was generally the first indication that ozone attack had occurred. The results of these tests are recorded in Table 172.

FACTUAL DATA (continued)

TASK B, Phase 2 (continued)

A study of these results shows that the same relationship between rate of attack and degree of elongation exists as did in the case of the dumbbell test pieces. However, the life of the sample in the ozone chamber is very much shorter in the case of the patch than in the case of the dumbbell test piece.

Generally, the life of the dumbbell had indicated that attack by ozone was a very improbable reason for failure of a balloon; however, the patch test with times to failure measured in seconds rather than in minutes indicates that failure due to ozone attack may indeed be a possibility.

A similar series of tests was next conducted using patches cut from a balloon manufactured from compound A3-106, and the results of these tests are recorded in Table 173.

A study of these results shows a completely different behavior than that shown with dumbbell test pieces. The rate of attack now appears to be completely independent of elongation.

At low elongations the time to failure is very much less than in the case of the patches manufactured from compound A3-105. At elongations approaching 600%, however, there is now virtually no difference between compounds A3-105 and A3-106.

The conclusions reached for the behavior of day-flight balloons based on the results obtained from dumbbell test pieces are still true when the patch test method of evaluation is used. The rate of attack is much greater at high elongations regardless of the method of test, and the increase in rate of attack shown by the bilaterally stretched sample compared with the unilaterally stretched sample merely indicates that the possibilities of failure by the methods described are more likely to occur.

However, in the case of the dual-purpose compound with the high plasticizer content, any conclusions based on the behavior of dumbbell testing must be discarded. The fact that the rate of attack is independent of the elongation now implies that the size of the balloon and the altitude to which it is intended to fly will have no bearing on the region or likelihood of failure due to ozone attack. The balloon designed to reach an altitude of 100,000 feet is just as likely to fail as the one designed to reach 150,000 feet, and furthermore, that failure will occur close to the layer of maximum ozone concentration which, generally speaking, is approximately 90,000 feet.

TABLE 172

OZONE ATTACK ON PATCHES CUT FROM A3-105 AND INFLATED TO VARIOUS ELONGATIONS

Elongation (%)	Exposure time in minutes											
	1	2	3	4	5	6	7	8	9	10	11	12
600	N	Broke										
600	N	Broke										
600	N	Broke										
400	N	N	Broke									
400	N	N	Deflated									
400	N	N	Deflated									
200	N	N	N	N	N	N	Deflated					
200	N	N	N	N	N	N	N	Deflated				
200	N	N	N	N	N	N	Deflated					
100	N	N	N	N	N	N	N	N	N	N	Deflated	
100	N	N	N	N	N	N	N	N	N	N	Deflated	
100	N	N	N	N	N	N	N	N	N	N	N	Deflated

TABLE 173

OZONE ATTACK ON PATCHES CUT FROM A3-106 AND INFLATED TO VARIOUS ELONGATIONS

Elongation (%)	Exposure time in seconds														
	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
600	N	N	N	N	N	N	N	C	C	C	VC	VC	VC	VC	Broke
600	N	N	N	N	N	N	C	C	C	VC	VC	Broke			
600	N	N	N	N	N	N	C	C	C	C	VC	VC	Broke		
400	N	N	N	N	N	C	C	C	C	VC	VC	VC	Deflated		
400	N	N	N	C	C	C	C	C	C	VC	VC	VC	Deflated		
400	N	N	N	C	C	C	C	VC	VC	VC	VC	Deflated			
200	N	N	N	N	N	N	N	C	VC	VC	VC	Deflated			
200	N	N	N	N	N	N	C	C	C	VC	VC	VC	Deflated		
200	N	N	N	C	C	C	C	C	VC	VC	VC	Deflated			
100	N	N	N	N	N	N	C	C	C	C	C	VC	Deflated		
100	N	N	N	N	N	N	C	C	C	C	C	VC	VC	VC	Broke
100	N	N	N	N	N	C	C	C	C	VC	VC	Deflated			

N — No attack
C — Film became cloudy
VC — Film became very cloudy and opaque

FACTUAL DATA (continued)

TASK B, Phase 2 (continued)

The increase in the rate of attack of the day-flight balloon compound as shown by patch testing which brings it to the same order as that of the dual-purpose compound further indicates that dual-purpose and day-flight balloons will be equally susceptible to failure due to attack by ozone, which is in contradiction to the conclusions reached if unilateral test results are used as a basis.

Since all previous evaluation of antiozonants has been conducted using dumbbell test pieces, it now becomes necessary to re-evaluate the whole program using patch testing as the standard method. As a preliminary step, investigation was made of the effect of increasing the quantity of antiozonant, in this case N.B.C., and also the effect of using Neoprene 400 which has inherently better ozone resistance than other neoprene polymers.

Modifications were made to compound A3-105, using 5, 8, and 10 parts of N.B.C. instead of the normal 3 parts. Patches were inflated to 400% elongation, and the time to burst or deflation was determined. At the same time, compound A3-130 which contains Neoprene 400 instead of Neoprene 571 was also evaluated by the same procedures, except that elongations of 400% and 600% were used.

The results of these tests are given in Table 174.

A study of these results shows that the ozone resistance of compound A3-105 can be substantially increased by raising the N.B.C. content from 3 parts to 8 parts. Raising the content to 5 parts was only slightly effective, and increasing the content from 8 parts to 10 parts showed no further improvement. However, at 400% elongation, the life in the ozone chamber is doubled when the N.B.C. content is raised to 8 parts.

Similarly, the use of Neoprene 400 also shows a significant improvement in resistance to ozone. This is less marked at 400% elongation than at 600% elongation, and in neither case is there an improvement comparable to that obtained by the use of 5 additional parts of N.B.C.

As reported in Task A, Phase 3, a compound designated A3-117 was developed which had almost identical physical characteristics as A3-105 but which was much superior in ozone resistance. If attack by ozone constitutes a serious problem, balloons made from compound A3-117 should show better and more consistent performance than equal balloons made from A3-105.

Since the only reason to expect better performance from A3-117 is its improved ozone resistance, the flights of balloons made from this compound are reported in Phase 5 of Task B.

FACTUAL DATA (continued)

TASK B. Phase 2 (continued)

TABLE 174

OZONE ATTACK ON PATCHES CUT FROM COMPOUND A3-130 AND MODIFICATIONS OF COMPOUND A3-105 CONTAINING ADDITIONAL N.B.C.

Compound	Parts of N.B.C.	Elongation (%)	Time to Deflation (seconds)
A3-105	3	400	160
A3-105	3	400	170
A3-105	5	400	210
A3-105	5	400	220
A3-105	8	400	360
A3-105	8	400	380
A3-105	10	400	400
A3-105	10	400	380
A3-105	3	400	180
A3-105	3	400	190
A3-130	3	400	230
A3-130	3	400	210
A3-105	3	600	120
A3-105	3	600	130
A3-130	3	600	180
A3-130	3	600	180

FACTUAL DATA (continued)

TASK B (continued)

Phase 3: Effect of Infra-Red Radiation

In order to clarify the effect of atmospheric conditions on balloon films, the services of consultants on atmospheric physics were obtained. Dr. Julius London and Dr. Herman Newstein, both of the Department of Meteorology at N y York University, were engaged and examined the theoretical aspects of the effect of atmospheric conditions on balloon films. Initially, their investigation was directed toward the effect of infra-red radiation since neoprene itself shows marked absorption bands in the infra-red spectrum.

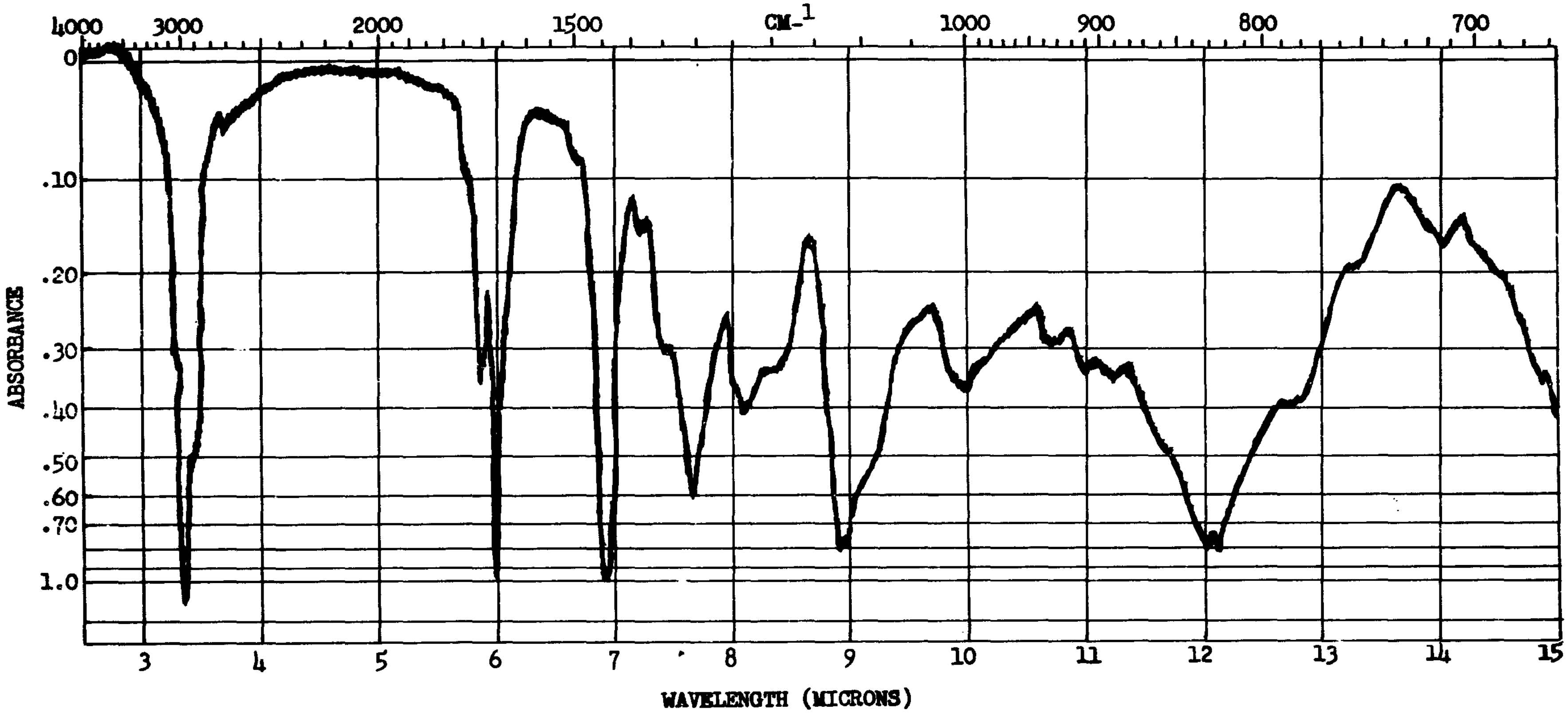
An absorption spectrum for neoprene was obtained from E.I. du Pont de Nemours and is reproduced in Figure 2.

Samples of the balloon film suitably mounted between metal washers were supplied to enable Dr. Newstein to determine the spectral characteristics of balloon film as opposed to the neoprene itself. According to du Pont, there is no significant absorption in the visible or ultra-violet.

Dr. Newstein's report on the spectral characteristics of the neoprene film is presented on the following pages.

FIGURE 2

INFRA-RED ABSORPTION SPECTRUM FOR NEOPRENE



Spectral characteristics of the Neoprene film

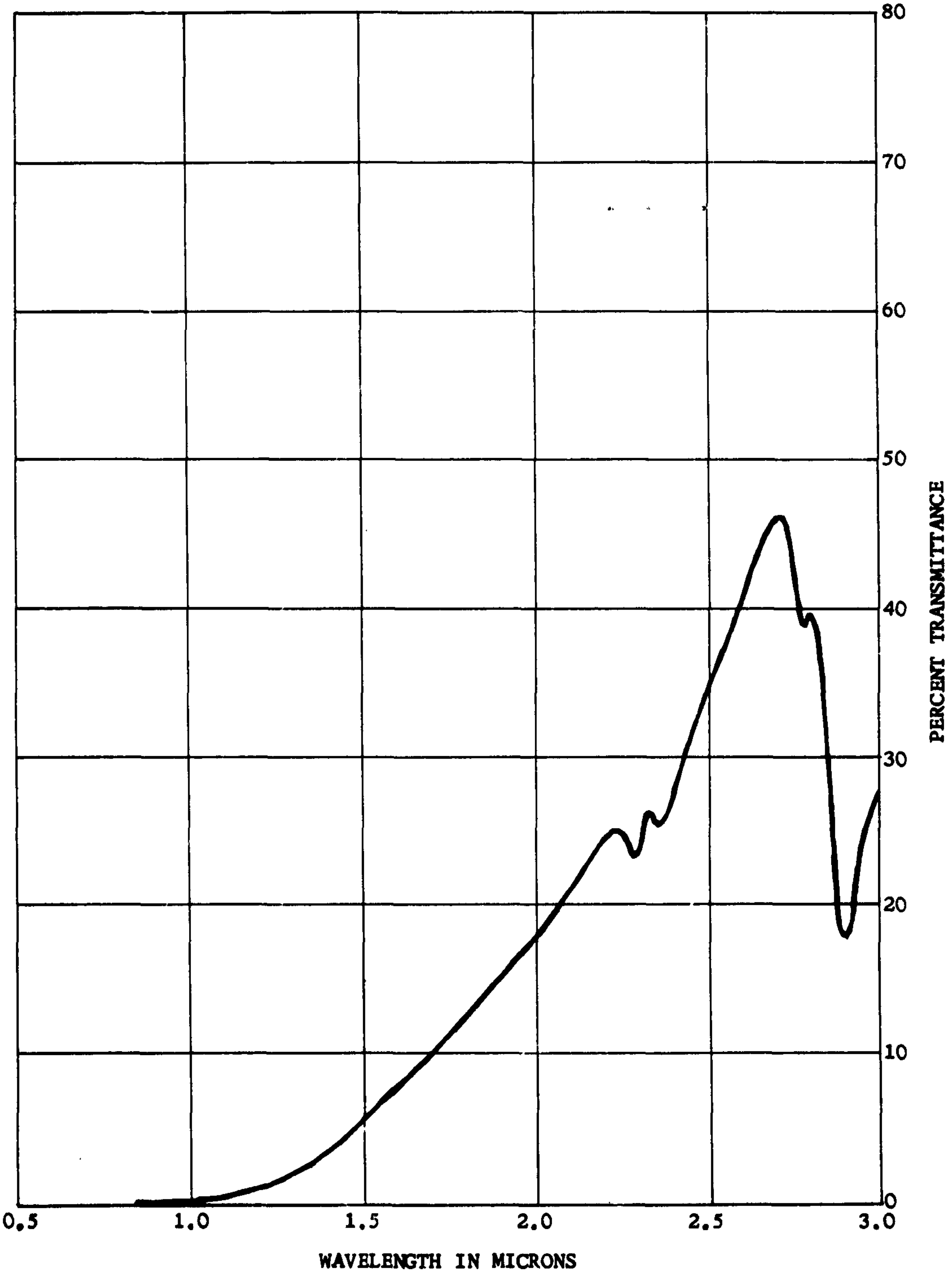
In order to make estimates of the radiation load on the balloon it was necessary to determine the spectral characteristics of the balloon film. That is, the nature of the variation of reflectivity, absorptivity and transmissivity as a function of wavelength. This is particularly important in view of the spectral ranges of solar and terrestrial radiation and the location of the water vapor, carbon dioxide and ozone absorption bands. These measurements of spectral character for the neoprene film are difficult to determine since spectro-photometers normally measure specular transmission. But total (specular and diffuse) reflectivity transmissivity and absorptivity measurements are really required.

In this report, only the specular transmission in percent was measured. If possible, the other measurements may be made for a future report. The measurements of spectral transmission in percent were made for the range from 0.28 microns to 16 microns. These were made for dual purpose neoprene film samples cut from balloon fabric. The spectrophotometric results are shown in subsequent figures.

Figure 1 presents the percent transmission of the unstretched neoprene film 3.3 mils thick. The range of wavelength covered is from one to three microns. The instrument used was the Beckman DK-2 recording spectro-photometer with a PbS detector. This figure shows that the transmission decreases regularly from 21 percent at 2.7 microns to near zero percent at one micron. Although it is not indicated, the transmission was still indicated to be near the zero level for all wavelengths shorter than one

FIGURE 3

SPECTRAL TRANSMISSION (PERCENT) OF DUAL-PURPOSE NEOPRENE FILM 3.3 MILS THICK FOR WAVELENGTH 1 TO 3 MICRONS



micron down to 0.2 microns.

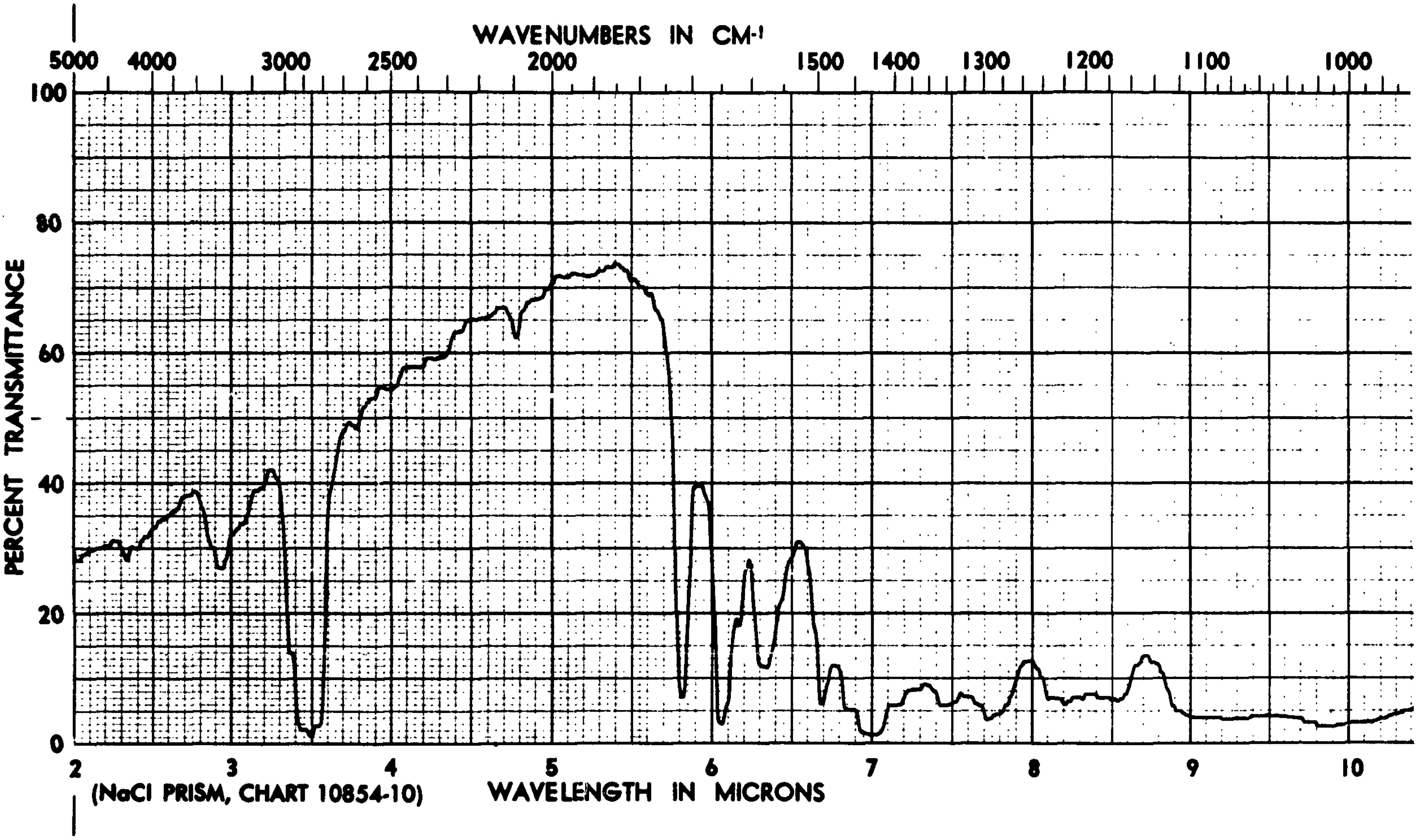
The spectral transmission for the same 3.3 mil sample over the range of wavelengths from 2 to 16 microns is shown on figure 4. These observations were made with a Baird-Atomic Inc. Infra-Red Spectrophotometer. The figure is a typical infrared neoprene transmission spectrum showing the absorption bands characteristic of neoprene through the range of wavelengths of meteorological significance.

Except for narrow absorption bands in the region near 3, 3.5, 5.8 and 6 microns, the transmission rose from 30 percent to near 70 percent. From 7 to 13 microns the transmission was generally less than 10 percent and was gradually increasing at wavelengths longer than 13 microns.

Additional transmission measurements were made for a film of the same compound neoprene but cast on a slide such that the film thickness was 0.2 mils. This was done so that the effect of absorption in the visible and near ultraviolet region of the spectrum could be evaluated for the balloon at relatively high elevations. A thickness of 0.2 mils is about 0.06 times the thickness of the flaccid film and corresponds to a balloon elongation of about 300 percent. This corresponds to an elevation of approximately 80,000 ft.

Figure 5 shows the spectral transmission for this sample in the near ultraviolet region. Here the transmission remains below 2 percent from about 0.28 microns to 0.34 microns. From 0.34 to 0.36 microns the transmission rises to near 11 percent. Figure 6 shows the continuation of this spectrum from 0.36 microns to 3 microns. There is a steady though nonlinear rise of transmission from 11 percent at 0.36 microns to

SPECTRAL TRANSMISSION (PERCENT) OF DUAL-PURPOSE NEOPRE
3.3 MILS THICK FOR WAVELENGTHS 2 TO 16 MICRON



1

ISSION (PERCENT) OF DUAL-PURPOSE NEOPRENE FILM
S THICK FOR WAVELENGTHS 2 TO 15 MICRONS

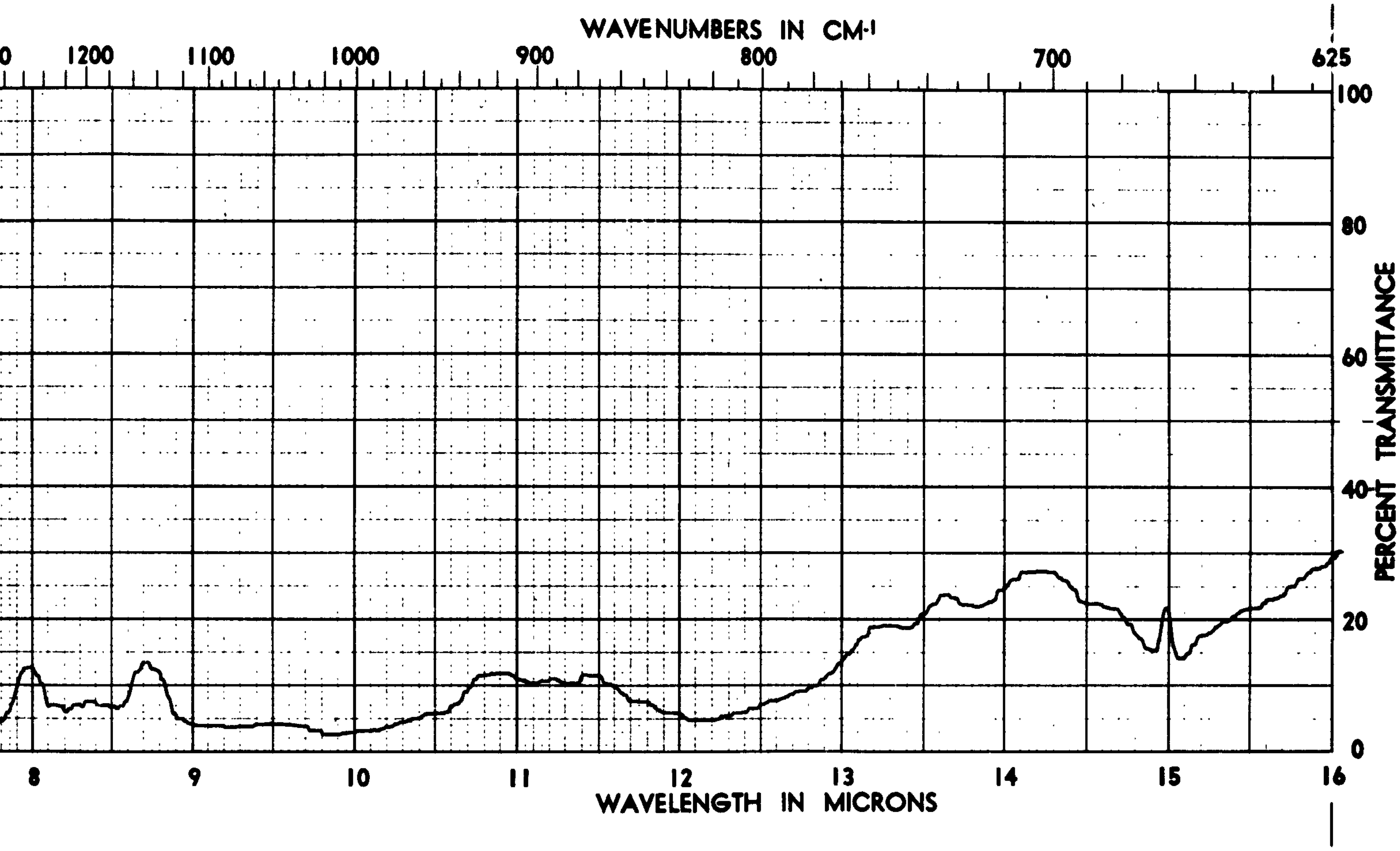


FIGURE 4

SPECTRAL TRANSMISSION (PERCENT) OF DUAL-PURPOSE NEOPRENE FILM 3.3 MILS THICK FOR WAVELENGTHS 2 TO 16 MICRONS

FIGURE 5

SPECTRAL TRANSMISSION (PERCENT) OF DUAL-PURPOSE NEOPRENE FILM 0.2 MILS THICK FOR WAVELENGTHS 0.28 TO 0.36 MICRONS

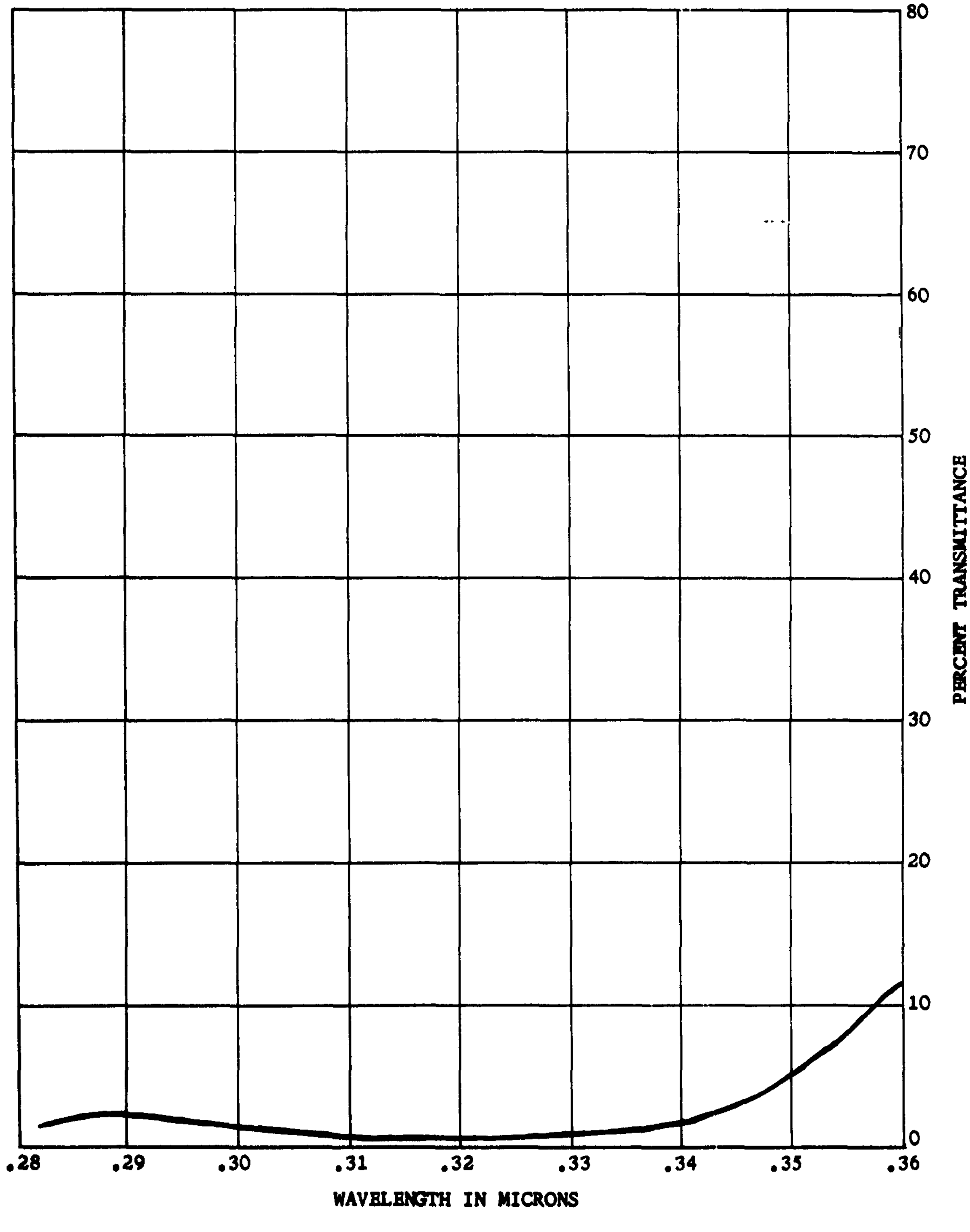
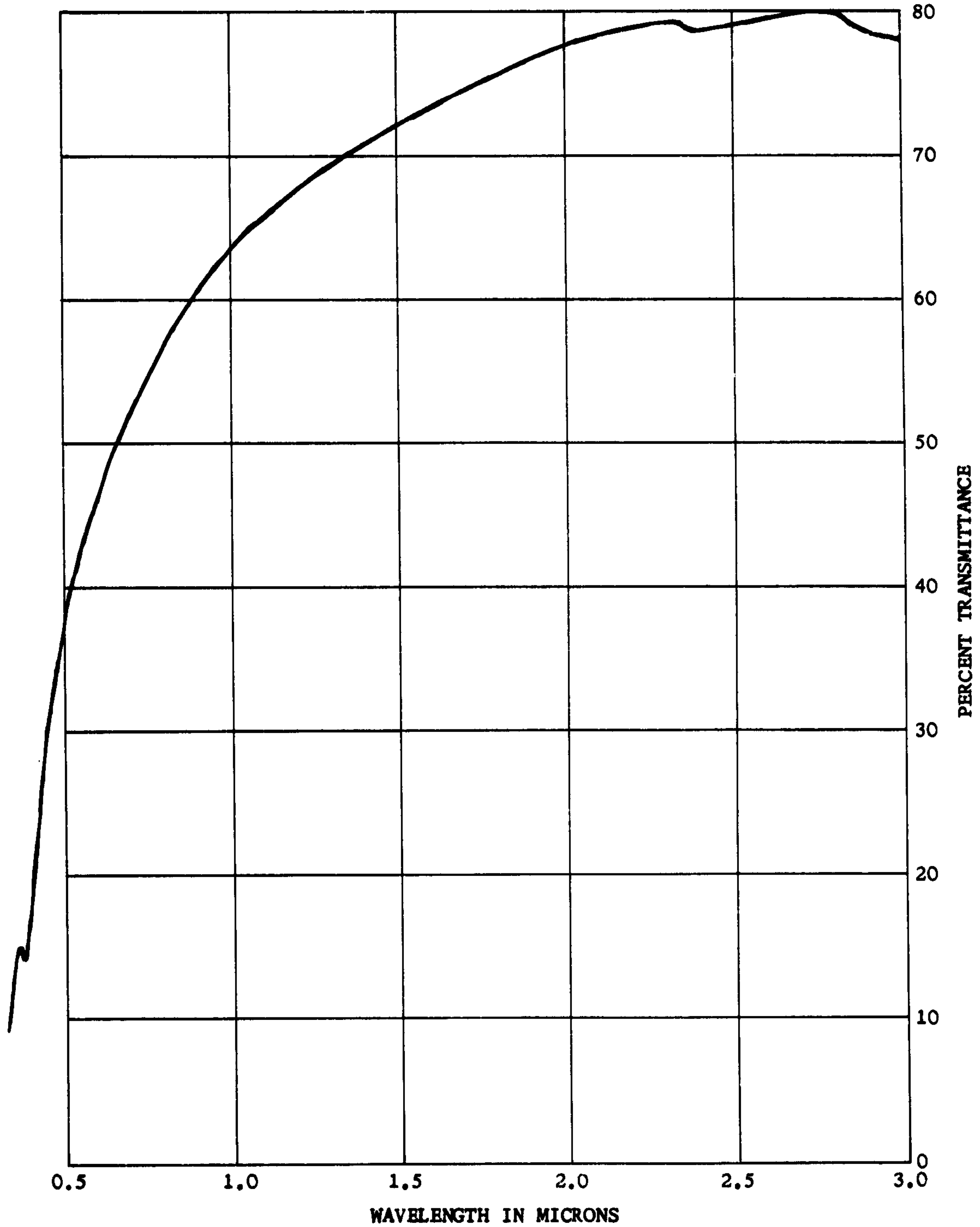


FIGURE 6

SPECTRAL TRANSMISSION (PERCENT) OF DUAL PURPOSE NEOPRENE FILM
0.2 MILS THICK FOR WAVELENGTHS 0.36 TO 3 MICRONS



near 80 percent at 2.7 microns.

A comparison of these spectra with those prepared by Polaroid Corp. in 1951 (Final Report, Molded Latex Products, Inc., USA, SCEL Contract No. W36-039-sc-33721 and DA 36-039-sc-4, 1952) indicates a much lower transmissivity for the neoprene film of this report particularly in the ultraviolet and visible region. This discrepancy is probably due to the differing opacity of the two films and does not necessarily indicate experimental error. However, it does point up the need for carefully prepared spectra for each particular compound of neoprene used in balloon films as the opacity of each film may be different from others.

These spectra, particularly for the near infrared and visible regions seem to indicate that lower transmission may be due in large part to scattering of the shorter wavelengths by the compound. In order to get a better measure of the absorptivity of the neoprene film, it is recommended that the following spectral measurements be made:

1. Diffuse and specular reflectivity.
2. Diffuse and specular transmissivity.
3. Determination of the effect of scattering on the apparent transmissivity.
4. Spectral measurements of 1 and 2 above with various angles of incident radiation.
5. Transmission and reflectance measurements for a range of 4 or 5 thicknesses to cover the change of thickness of the balloon film as it rises from the ground to near 120,000 ft.

References

Golishev, G. E., 1959: Investigation of the gas temperature in balloons during ascent. Transactions of the Central Aerological Observatory, Moscow, pp. 36-45.

Plass, G.N., 1956: The influence of the 15μ carbon-dioxide band on the atmospheric infrared cooling rate. Q. J. Roy. Met. Soc., 82, 310-324.

THE RADIATION LOAD ON A BALLOON IN THE FREE ATMOSPHERE (Part 1)

If we assume that the hydrogen in the balloon is completely mixed and that the vertical temperature gradient within the balloon is small, and that the gas and balloon temperature are the same, we have in general

$$c \frac{dT_B}{dt} = S + A - E - G + K \qquad (1)$$

where c represents the total heat capacity of the gas-balloon system;

$c = M c_N + m c_p$ where M, m are the mass of the balloon film and hydrogen, c_N and c_p are the specific heat capacity of the neoprene and the specific heat at constant pressure of the hydrogen.

dT_B/dt is the temperature change of the balloon-gas system as it ascends.

S represents the effect of incoming solar radiation.

A is the infra-red absorption of the balloon film.

E is the total infra-red emission of the balloon.

G is the local temperature change due to the expansion of the gas in the balloon.

K is the effect of conduction through the balloon.

Since H_2 has no absorption in the visible or infra-red, it will be assumed that the film absorption acts to heat (or cool) the film and gas combined, the latter by conduction and convection within the balloon. We also assume a spherical balloon.

1. **The total insolation**

If we assume infinite conduction (i.e., a short time lag along the balloon film and within the gas), the solar energy absorbed by the balloon is:

$$S = \pi r^2 \int_0^\infty a_\lambda I_\lambda \downarrow d\lambda + 2\pi r^2 \int_0^\infty a_\lambda I_\lambda \uparrow d\lambda \qquad (2)$$

where $I\downarrow$ is the direct insolation from above and

$I\uparrow$ is the diffuse insolation reflected from below.

For clear skies we take $I_\lambda \uparrow = 0.20\ I_\lambda \downarrow$.

For cloudy skies we take $I_\lambda \uparrow = 0.50\ I_\lambda \downarrow$.

r is the radius of the balloon which changes during the flight time;

a_λ is the absorptivity of the film through the visible region of the spectrum. The direct insolation from above is perpendicular to the cross-sectional area of the balloon whereas the upwelling diffuse radiation falls evenly on the bottom hemisphere of the balloon. At high elevations the incoming solar radiation is not strongly depleted and we can assume that $\int_0^\infty I_\lambda \downarrow d\lambda$ is equal to the solar constant ≈ 2 cal cm^{-2} min^{-1}. Therefore

$$\int_0^\infty I_\lambda \uparrow d\lambda \text{ (clear)} \approx 0.4 \text{ cal cm}^{-2} \text{ min}^{-1}$$

$$\int_0^\infty I_\lambda \uparrow d\lambda \text{ (cloudy)} \approx 1.0 \text{ cal cm}^{-2} \text{ min}^{-1}.$$

Moreover, we will assume that the scattering is white for both clear and cloudy skies (i.e., the relative spectrum for $I_\lambda \uparrow$ is the same in both cases as for $I_\lambda \downarrow$).

Then we can write for

$$\text{clear skies} \quad S = 1.4\,\pi r^2 \int_0^\infty a_\lambda I_\lambda \downarrow d\lambda \tag{3a}$$

$$\text{cloudy skies} \quad S = 2\pi r^2 \int_0^\infty a_\lambda I_\lambda \downarrow d\lambda \tag{3b}$$

If we assume that the balloon is gray in the visible with an absorptivity of 0.2 corresponding to a film thickness of 0.2 mil (approximately 80,000 ft elevation), the insolational load on the balloon would be from the above:

For clear skies

$$S = \pi r^2 (1.4)(0.2)(0.4) \text{ cal cm}^{-2} \text{ min}^{-1}$$
$$= 0.11 \times \pi r^2 \text{ cal min}^{-1} \tag{4a}$$

For cloudy skies

$$S = \pi r^2 (2)(0.2)(1.0) \text{ cal cm}^{-2} \text{ min}^{-1}$$
$$= 0.4 \times \pi r^2 \text{ cal min}^{-1}\,. \tag{4b}$$

2. <u>The infrared load on the balloon</u>

a. <u>Emission</u>

If the balloon film has an absolute temperature (T_B) the total emission from the balloon surface is given by

$$E = 4\pi r^2 \int_0^\infty a_\lambda f_{b\lambda}(T_B)\, d\lambda \tag{5}$$

where $f_{b\lambda}$ is the specific black body radiation at wavelength λ and temperature T_B.

b. <u>Absorption</u>

The total radiation absorbed by the balloon is given by

$$A = 2\pi r^2 \int_0^\infty a_\lambda f_\lambda \uparrow d\lambda + 2\pi r^2 \int_0^\infty a_\lambda f_\lambda \downarrow d\lambda$$
$$= 2\pi r^2 \int_0^\infty a_\lambda (f_\lambda \uparrow + f_\lambda \downarrow) d\lambda \tag{6}$$

where $f_\lambda \uparrow$ and $f_\lambda \downarrow$ represent the specific flux of infrared radiation reaching

the balloon from below and above the level of the balloon.

Radiometers in the free atmosphere generally measure the net total radiation flux (i.e., $F\uparrow - F\downarrow$) rather than the upward and downward flux components separately. Also, theoretical computations are generally made of the net flux. However, Plass (1956) has shown that at levels above 60,000 ft even in the spectral interval 12-18μ (strong carbon dioxide absorption), the difference between the total flux ($f\uparrow + f\downarrow$) and the net flux ($f\uparrow - f\downarrow$) is relatively small, as shown in the following table.

Flux given in 10^{-2} cal/cm^2/min for 12-18μ.

	$f\uparrow$	$f\downarrow$	$f\uparrow + f\downarrow$	$f\uparrow - f\downarrow$	$\frac{f\uparrow + f\downarrow}{f\uparrow - f\downarrow}$
60,000 ft	9.0	1.0	10.0	8.0	1.25
90,000 ft	9.0	0.5	9.5	8.5	1.11

For the remaining spectral region (except for the relatively unimportant interval around 9.6μ) the ratio of the total to net flux is much closer to 1 than is shown in the table. Thus as an approximation we can assume that the absorption by the balloon is given by

$$A = 2\pi r^2 \int_0^\infty a_\lambda f_{net}\, d\lambda \tag{7}$$

If we now combine the effects of absorption and emission, we have

$$\begin{aligned} A - E &= 2\pi r^2 \int_0^\infty a_\lambda f_{net}\, d\lambda - 4\pi r^2 \int_0^\infty a_\lambda f_{b\lambda}\, d\lambda \\ &= 2\pi r^2 \int_0^\infty a_\lambda (f_{\lambda_{net}} - 2f_{b\lambda})\, d\lambda \ . \end{aligned} \tag{8}$$

In general, $2f_{b\lambda} > f_{\lambda_{net}}$ and the balloon cools as a result of infrared exchange. This is essentially because the balloon receives radiation only from below

but emits infrared radiation in all directions. Also, it can be seen from equation (8) that if the balloon is uniformly blackened (i.e., a_λ is increased) the radiative loss is increased.

The following is a sample numerical calculation for a height of approximately 80,000 ft for clear and cloudy skies, and for January and July. For the purpose of the calculation it is assumed that the balloon has an average absorptivity (a_λ) in the infrared of 0.5.

	Clear		Cloudy	
	Jan.	July	Jan.	July
F_{net}	0.295	0.366	0.273	0.336
F_b (T_b = 228°K)	0.223		0.223	
F_b (T_b = 217°K)		0.180		0.180

where F_{net} and F_b are the total net flux and black body flux ($F_b = \sigma T^4$) respectively and are given in cal cm^{-2} min^{-1} at 80,000 ft and where σ is the Stefan-Boltzman constant taken to be 0.817 x 10^{-10} cal cm^{-2} min^{-1} deg^{-4}. The temperatures have been assumed to correspond to the mean free air temperature during January and July at 80,000 ft. Thus we have at 80,000 ft the net infrared exchange from equation (8):

$$A - E = 2\pi r^2 (0.5)(F_{net} - F_b) \tag{9}$$

a. Jan. clear $\quad A - E = -0.075\,(2\pi r^2)$

b. July clear $\quad = +\,0.003\,(2\pi r^2)$

c. July cloudy $\quad = -\,0.086\,(2\pi r^2)$

d. July cloudy $\quad = -\,0.012\,(2\pi r^2)$

Only during the summer with clear skies is there sufficient infrared radiation from below (on the average) to result in a radiative gain by the balloon.

It should be pointed out that these results are approximate and represent estimates of the radiation load rather than final computations.

The change in temperature of the balloon (hydrogen plus neoprene) is due not only to the influences of radiative exchange of heat between the balloon and its environment as discussed above but also to several additional factors. These are the exchange of heat by conduction between the balloon and the ambient atmosphere, the change of temperature of the hydrogen due to expansion as the balloon rises and the subsequent exchange of heat between the neoprene and the hydrogen, and finally, the change in temperature of the neoprene film itself as it is stretched (a sort of internal friction). This latter will be neglected in this treatment.

3. Change of temperature due to expansion

The rate of change of temperature of the hydrogen in the balloon due to expansion will be discussed. For this treatment, the expansion of the balloon will be considered to be adiabatic. The non-adiabatic effects of radiation have been discussed above and the non-adiabatic conduction will be treated later. The first law of thermodynamics for the adiabatic expansion of the hydrogen in the balloon may be written in the form

$$dq = m c_p dT - m \alpha dp = 0 \qquad (10)$$

where m is the mass of the hydrogen,

dq is the change in heat,

c_p is the specific heat capacity of constant pressure for hydrogen,

dT is the change in temperature of the hydrogen,

α is the specific volume of the hydrogen, and

dp is the change in pressure of the hydrogen.

Substituting for α from the equation of state for an ideal gas

$$\alpha = RT/p$$

where R is the gas constant for the gas,

T is the absolute temperature of the gas, and

p is the pressure of the gas.

Equation (10), when the differentiation is performed with respect to elevation (z) becomes

$$\frac{dT}{dz} = \frac{RT}{c_p p}\frac{dp}{dz} \tag{11}$$

It is now assumed that the gas in the balloon is always in dynamic equilibrium with the ambient air environment. This is to say that the pressure inside the balloon is determined by and is equal to the pressure of the air outside the balloon. The pressure due to the tension in the balloon fabric is considered to be quite small. Consequently, the variation of pressure in the balloon as it rises is determined by the vertical variation of pressure in the atmosphere.

It is further assumed that the atmosphere is in hydrostatic equilibrium. The hydrostatic equation for the atmosphere may be written as:

$$\frac{dp'}{dz} = -\rho' g = -\frac{p'g}{RT'}$$

Here, primed variables refer to the environment.

Since $p = p'$, equation (11) becomes

$$\frac{dT}{dz} = -\frac{gR}{c_p R'}\frac{T}{T'} \tag{12}$$

Thus the rate at which the temperature in the balloon varies with

elevation depends upon the rate of change of temperature due to the isolated adiabatic expansion of the gas (gR/c_pR') multiplied by the ratio of the absolute temperature in the balloon relative to the air. From observations as indicated below, a relative extreme value for T/T' can be as much as 260°/220°. Then the difference between T and T' is usually rather small, and for the most part

$$\frac{dT}{dz} = -\frac{gR}{c_pR'} \tag{12a}$$

For hydrogen, $c_p = 3.4$ cal gm^{-1} deg^{-1}, $\frac{R}{R'} = 14.3$

$$\frac{dT}{dz} \approx -9.75^\circ\text{C per km or } -3.0^\circ\text{C per 1000 ft.}$$

The assumption was made above that the neoprene film always remains at the same temperature as the hydrogen inside the balloon. This argument was based upon the considerations that heat in the neoprene is transported not only via thermal conductivity but by radiative processes as well. Further, due to the high heat conductivity of hydrogen (about 10 times that of air, and nearly the same as that for the neoprene) and thorough mixing inside the balloon due to turbulence and convection, the gas and neoprene tend to reach the same temperature. Consequently, part of the cooling of the hydrogen due to its expansion must be used to cool the neoprene in contact with it. This additional cooling will depend upon the mass and specific heat of the neoprene.

In this case, considering the balloon (gas and neoprene) as a thermodynamic system, the first law may be written as:

$$dq = m\,c_p\,dT - m\alpha\,dp + M\,c_N\,dT = 0 \tag{13}$$

where M is the mass of the neoprene, and

c_N is the specific heat capacity of the neoprene.

The other variables have been defined above.

Equation (12a) becomes, then

$$\frac{dT}{dz} = - \frac{mg\,R}{(m\,c_p + M\,c_N)\,R'} \tag{14}$$

As an example, for the 1000 gm balloon:

$m = 212$ gm

$M = 1000$ gm

$c_N = .5 \text{ cal cm}^{-1}\,{}^\circ K^{-1}$

$\frac{dT}{dz} \simeq -5.9^\circ C \text{ km}^{-1}$ or $-1.8^\circ C$ per 1000 ft.

To convert this adiabatic component of temperature change with elevation to rate of change, it is necessary to know the rate of ascent of the balloon. Thus:

$$\frac{dT}{dt} = \frac{dT}{dz} \cdot \frac{dz}{dt} = w\,\frac{dT}{dz} \tag{15}$$

Normally, w is about 1000 ft per minute, so:

$$\frac{dT}{dt}_{adiabatic} = -1.8^\circ C \text{ min}^{-1}$$

4. <u>The effect of conduction through the balloon</u>

The next effect to be considered is the rate at which heat is exchanged between the balloon and the surrounding air by the mechanism of conduction through the neoprene film. The situation is considered in which the hydrogen inside the balloon is at one temperature (T_B), the air outside the balloon is at temperature (T_A) and a gradient of temperature exists in the neoprene ($T_B - T_A$). In this case, the rate of heat loss by the balloon

may be expressed as:

$$\frac{dq}{dt} = \frac{k\,D(T_B - T_A)}{\delta} \qquad (16)$$

where dq/dt is the rate of loss of heat of the balloon,

k is the coefficient of heat conductivity of the neoprene,

D is the surface area of the balloon,

$(T_B - T_A)$ is the temperature across the neoprene film, and

δ is the thickness of the neoprene film.

In equation(16), D, $(T_B - T_A)$, and δ are functions of elevation and time. T_A is determined by the lapse rate γ of the ambient air. One may derive an expression for D and δ as functions of elevation by making use of the gas law in the following manner.

A constant lapse rate is assumed for the atmosphere of -5.25°C per km or -1.6°C per 1000 ft up to 50,000 ft and +1.1°C per km or 0.3°C per 1000 ft above 50,000 ft. In this case, the pressure at any level may be expressed in terms of the pressure at the ground and the lapse rate γ as:

$$p = p_o\left(1 - \frac{\gamma z}{T_o}\right)^{g/R\gamma} \qquad (17)$$

where p_o and T_o are the ground air pressure and temperature respectively,

g is the acceleration of gravity, and

R is the gas constant for air.

Since, from the gas law, pV = constant,

$$\frac{D_1}{D_o} = \left(\frac{p_o}{p_1}\right)^{2/3}$$

or

$$D = D_o\left(1 - \frac{\gamma z}{T_o}\right)^{\frac{2}{3}\frac{g}{R\gamma}} \tag{18}$$

As far as the thickness of the neoprene as a function of height is concerned, experiments performed stretching the neoprene balloon film show that the volume of the neoprene is very nearly conserved.

$$D\delta = \text{constant}$$

Therefore

$$\delta = \delta_o\left(1 - \frac{\gamma z}{T_o}\right)^{-\frac{2}{3}\frac{g}{R\gamma}} \tag{19}$$

On substituting back into equation (16)

$$\frac{dq}{dt} = k\frac{D_o}{\delta_o}\left(1 - \frac{\gamma z}{T_o}\right)^{\frac{4}{3}\frac{g}{R\gamma}}(T_B - T_A) \tag{20}$$

There are many difficulties in trying to use the analytic approach of equation (20) directly in connection with the balloon. In particular, gradients of temperature which may be quite large are set up in the boundary layer of the hydrogen as well as the air and these gradients may not be constant over the surface of the balloon. In view of the uncertainties involved in the discussion above, it is useful to consider as a first estimate, the case where the balloon (film and gas) is considered a unit, with the neoprene always at the same temperature as the gas. In this case, one may consider the balloon analogous to a thermometer with a finite lag time. The response of a thermometer to changes of temperature in the environment is well known:

$$\frac{dT_B}{dt} = -\frac{1}{\lambda}(T_B - T_A) \tag{21}$$

where T_B is the balloon temperature,

T_A is the ambient air temperature which is not affected by the balloon,

λ is the lag coefficient or "time constant".

If T_A is considered a linear function of height (or time) as is very nearly the case on the average, the lapse rate is then

$$T_A = T_o + \beta t \tag{22}$$

where T_o is the temperature at the reference level,

β is the rate of change of temperature of the air with time and is equal to $w \cdot \gamma$.

Then

$$\frac{dT}{dt} = -\frac{1}{\lambda}[T_B - (T_o + \beta t)] \tag{23}$$

Now, if T_B were initially in equilibrium with the environment, then:

$$T_B - T_A = -\beta\lambda(1 - e^{-t/\lambda}) \tag{24}$$

and after a time interval $t >> \lambda$

$$T_B - T_A = -\beta\lambda \tag{25}$$

In this case λ is not well known. It depends upon many physical parameters such as the size and shape of the balloon, the rate of ventilation of the balloon, and the thermal conductivity of the balloon surface. The ventilation of the balloon itself is of the form

$$\lambda = K v^n \tag{26}$$

where v is the velocity of the air ventilating the balloon and K is a function including the air density and the area of the balloon surface. It is known that the larger the area of the balloon, and the larger the density of the air, the more efficient will be the response of the balloon to the change in temperature of the environment.

Actually the change in surface area and the change in density of the air as the balloon rises act to counterbalance each other. One may then conclude that as a first approximation the lag time of a rising balloon is constant for each particular rate of ascent. Gilishev (1959) has made measurements of the time lag of response of a balloon in a wind tunnel and concluded that for a wind speed of 6 m/sec (i.e., speeds similar to those encountered in a balloon flight) $\lambda = 100$ sec. Substituting for $\beta = -.027°C\ sec^{-1}$ and $\lambda = 100$ sec in equation (25), one finds

$$T_B - T_A = 2.7°C \text{ after 10 minutes.}$$

For an extreme value of $T_B - T_A$ as shown in the ascent diagrams, 35°C may be used. For this temperature difference we have from equation (21), assuming $\lambda = 100$ sec:

$$\left.\frac{dT}{dt}\right|_K = \frac{35 \times 60}{100} = 21°C\ min^{-1}.$$

5. Preliminary results

A. From equations (1), (4a), and (4b), we can write:

$$\left.\frac{dT_B}{dt}\right|_S = \frac{0.11\,\pi r^2}{c} = 39.4°C\ min^{-1} \text{ for clear skies and}$$

$$= \frac{0.4\,\pi r^2}{c} = 141°C\ min^{-1} \text{ for cloudy skies.}$$

This is for $r = 12$ ft and heat capacity of balloon system $(c) = 1220$ cal deg^{-1}.

B. From equations (1) and (7),

$$\left.\frac{dT_B}{dt}\right|_A = \frac{0.33\,\pi r^2}{c} = 116°C\ min^{-1} \text{ for clear skies and}$$

$$= \frac{0.305\,\pi r^2}{c} = 107°C\ min^{-1} \text{ for cloudy skies.}$$

These values above are for January and July averaged (taken from table

on page 271.

C. From equations (1) and (5),

$$\left.\frac{dT_B}{dt}\right|_E = \frac{0.4\,\pi r^2}{c} = -142\,°C\ \text{min}^{-1}\ .$$

The net radiative effect is represented by A. + B. +C. during the daytime and by B. +C. at night. It can be seen from the above consideration that the total radiation load on the balloon for cloudy skies will be much larger than for clear skies during the daytime. During the night, however, the infrared radiation load on the balloon leads to approximately equal cooling for clear and cloudy skies.

The numbers quoted above can be used only qualitatively since both the effect of conduction (equation 21) and the black body radiation increases as the balloon temperature increases. If the balloon were to be in complete radiative equilibrium, we have from equation (1),

$$\frac{dT_B}{dt} = 0 = \frac{1}{c}(S + A - E) \tag{27}$$

Then from equations (4a), (4b), (5), and (7) we have

$$2\pi r^2 \sigma T_B^{\,4} = \pi r^2 F_{net} + 0.11\,\pi r^2 \quad \text{for clear skies, and}$$

$$2\pi r^2 \sigma T_B^{\,4} = \pi r^2 F_{net} + 0.4\,\pi r^2 \quad \text{for cloudy skies,}$$

where a_λ has been assumed to be 0.5 for the infrared and 0.2 for the visible absorption. Then, for radiative equilibrium,

$$T_B \approx 228\,°K \quad \text{for clear skies at 80,000 ft, and}$$

$$\approx 256\,°K \quad \text{for cloudy skies at 80,000 ft.}$$

Thus we see that the radiative equilibrium temperature is about 30°C higher for cloudy than for clear skies and that temperatures are higher than the mean observed temperature (220°K) at this elevation.

THE RADIATION LOAD ON A BALLOON IN THE FREE ATMOSPHERE (Part 2)

1. Introduction

As was pointed out in the previous report, the temperature change of a high-altitude balloon is due to five different factors:

a. heating due to absorption of solar radiation (S)

b. heating due to absorption of long-wave terrestrial radiation (A)

c. cooling due to long-wave radiation by the balloon (E)

d. cooling due to adiabatic expansion of the gas within the balloon as the balloon rises (G)

e. cooling or heating of the balloon due to conduction between the balloon and the surrounding air (K)

The conductive cooling or heating depends on the sign of the temperature difference (T_B-T_A) where T_B and T_A refer to the balloon and air temperature, respectively.

It was shown in the previous report that, when compared to the radiative factors, the rate of temperature change due to adiabatic expansion was negligible, and that except for extreme cases, the effect of conduction was quite small. These effects will therefore be omitted in the following discussion as being of secondary importance.

In the absence of adequate laboratory data, previous computations of the radiation load on the neoprene balloon were based on the assumption of a "gray" absorbing body (i.e., constant absorptivity over the spectrum). This assumption can lead to significant errors, particularly in the case of the absorption of atmospheric radiation (see, for instance, Möller, 1959).

In the following discussion, the radiation load is re-evaluated on the basis of the observed spectral distribution of the balloon transmissivity in the range 0.3μ to 16μ. It will again be assumed that the balloon is spherical, the conductivity of the balloon film is very large, and the gas temperature within the balloon is uniform. The following discussion will apply to a level of 80,000 feet (about 25 km), since this is the region of critical heat load on the balloon.

A. Absorption of Solar Radiation

During the daytime, the balloon absorbs solar radiation as direct radiation from above and as diffuse back scattered radiation from below. For the important levels of study of the solar load on the neoprene balloon ($>$80,000 feet), the incoming solar radiation is approximately equal to the extra-terrestrial radiation at the top of the atmosphere. For average conditions, the effective load on the balloon is the solar constant times the cross sectional area of the balloon. The total absorption combining the effect of direct and diffuse solar radiation currents is then given by

$$S \text{ (clear sky)} = 2.8\pi R^2 \int_0^\infty a_\lambda I_{o_\lambda} d\lambda \tag{1a}$$

$$S \text{ (cloudy skies)} = 4\pi R^2 \int_0^\infty a_\lambda I_{o_\lambda} d\lambda \tag{1b}$$

where:

R is the balloon radius

a_λ is the effective absorptivity for double balloon thickness and average directional incidence

I_{o_λ} is the spectral distribution of solar radiation at the top of the atmosphere on a unit surface perpendicular to the solar beam.

According to Johnson (1954), the value of

$$\int_0^\infty I_{o_\lambda} d\lambda = 2.0 \text{ cal cm}^{-2} \text{ min}^{-1}$$

Equations (1a) and (1b) are the same as (3a) and (3b) of the previous report except for a factor of 2. The difference arises from the fact that at the atmospheric levels considered, the transmissivity of the balloon film is greater than 70 per cent from 0.3μ to 0.5μ and over 90 per cent beyond 0.5μ. Thus the solar radiation is partly absorbed in practically equal amount by both upper and lower balloon surfaces.

B. Infra-red Load on the Balloon

From the previous report, the total infra-red absorption by the balloon is:

$$A = 4\pi R^2(1.5)\int_0^\infty a_\lambda f_\lambda d\lambda \qquad (2)$$

and the infra-red emission by the balloon is:

$$E = 4\pi R^2 x 2(1.5)\int_0^\infty a_\lambda f_{b\lambda} d\lambda \qquad (3)$$

where f_λ and $f_{b\lambda}$ are the atmospheric and black body fluxes arriving at and leaving the balloon film. The black body flux ($f_{b\lambda}$) is a function of the film temperature.

The factor (1.5) is introduced to account for the fact that the effective thickness of the neoprene film is increased because of the diffuse nature of the infra-red radiation at the balloon surface. In equation (3), it has been assumed that because of the small absorptivity, both sides of the film radiate to space.

The total radiation load on the balloon is given by equations (1), (2), and (3) for varied conditions of solar radiation, infra-red radiation, and cloudiness. It is apparent that the radiation load depends on such quantities as:

$$\int_0^\infty a_\lambda I_{o\lambda} d\lambda, \quad \int_0^\infty a_\lambda f_\lambda d\lambda, \text{ and } \int_0^\infty a_\lambda f_{b\lambda} d\lambda$$

$I_{o\lambda}$, f_λ, and $f_{b\lambda}$ can be approximated or computed from known parameters. Values of the balloon absorptivity (a_λ), for the total spectral interval desired, however, must be inferred from laboratory measurements.

2. Laboratory Data

Some of the spectral characteristics of the neoprene film were presented in the preceding report. That discussion will be extended and revised in this section.

If a light beam of specific intensity (I_λ) irradiates a substance, the intensity of the light absorbed, reflected, and/or transmitted is given by the following:

$$A = \alpha_\lambda I_\lambda$$

$$R = \rho_\lambda I_\lambda$$

$$T = \tau_\lambda I_\lambda$$

where α_λ, ρ_λ, and τ_λ are called the specific absorptivity, reflectivity, and transmissivity of the substance. It should be noted that

$$\alpha_\lambda + \rho_\lambda + \tau_\lambda = 1$$

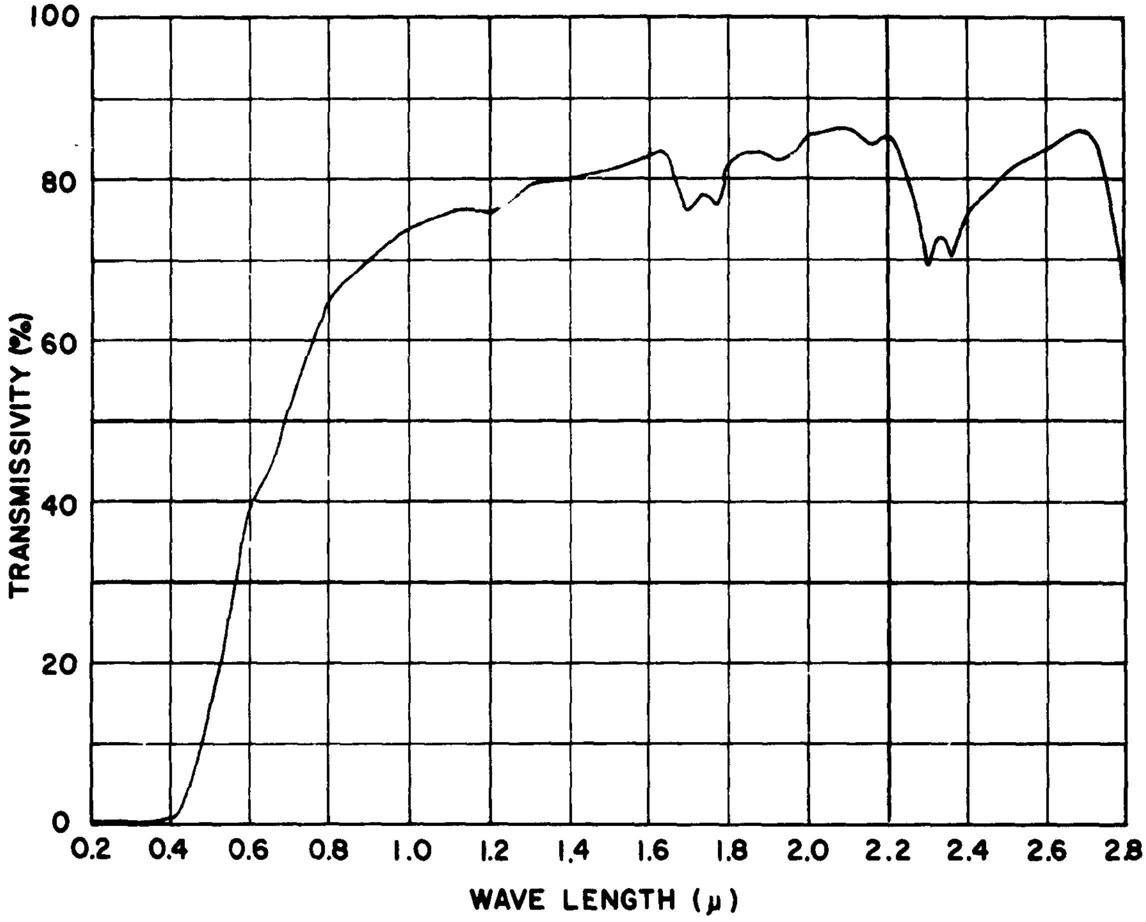
for any particular substance.

In general, it is quite difficult to observe the absorptivity directly. As a result, the transmission and reflection are measured and the specific absorption (and absorptivity) is inferred. In this case, the spectral characteristics of the unstretched and stretched neoprene film were determined in the following manner.

A Beckman Instruments' DK spectrophotometer with an integrating sphere attachment was used to measure the total (direct and diffuse) transmission of the unstretched neoprene film 3.3 mils thick. Figure 7 gives the value of the transmissivity in percent for the wavelength range from 0.35μ to 2.8μ. This curve shows a regular rise in total transmissivity of from less than 1 percent at 0.4μ to about 80 percent at about 1.3μ. From this value to 2.8μ the transmissivity remained generally over 70 percent with some indication of absorption bands around 1.7μ, 2.3μ, and 2.8μ.

FIGURE 7

TOTAL TRANSMISSIVITY OF 3.3 MIL NEOPRENE FILM



In the range from 0.2μ to 0.35μ (not shown) the transmissivity was uniformly less than 1 percent.

These results, when compared with the transmissivity curve (Figure 3, page 240) of the preceding report, indicate that practically all of the transmissivity below 1μ is of diffuse light.

The same instrument used to measure the total transmissivity also has the capability of measuring the total reflectivity. The reflectivity for the wavelength interval from 0.35μ to 2.8μ is shown in Figure 8. In this case, the standard procedure for making the measurement was modified to the extent that the sample holder was removed and the neoprene film was clamped directly over the sample opening. This modification was necessary since the transmission of the film was so high that reflection from the sample holder itself was retransmitted through the film and gave a spuriously high value for the reflectivity.

Figure 8 shows that the reflectivity increased from about 3 percent at 0.4μ to a maximum of about 27 percent at about 0.8μ and then fell gradually to about 10 percent in the range from 2.3 to 2.8μ. The same absorption bands at 1.7μ and 2.3μ that appear in the transmissivity curve also appear here. Also, the reflectivity in the range from 0.2μ to 0.35μ (not shown) was about 2 to 3 percent.

The spectral absorptivity in the range from 0.35μ to 2.8μ was then deduced from these two curves by making use of the relationship

$$\alpha_\lambda = 1 - \rho_\lambda - \tau_\lambda$$

This is presented as the upper curve in Figure 9. Since it was not practicable at the time to modify the spectrophotometers to accept a clamp holding stretched film, the spectral absorption characteristics for neoprene film 1/16 its flaccid thickness was deduced in the following manner:

FIGURE 8

TOTAL REFLECTIVITY OF 3.3 MIL NEOPRENE FILM

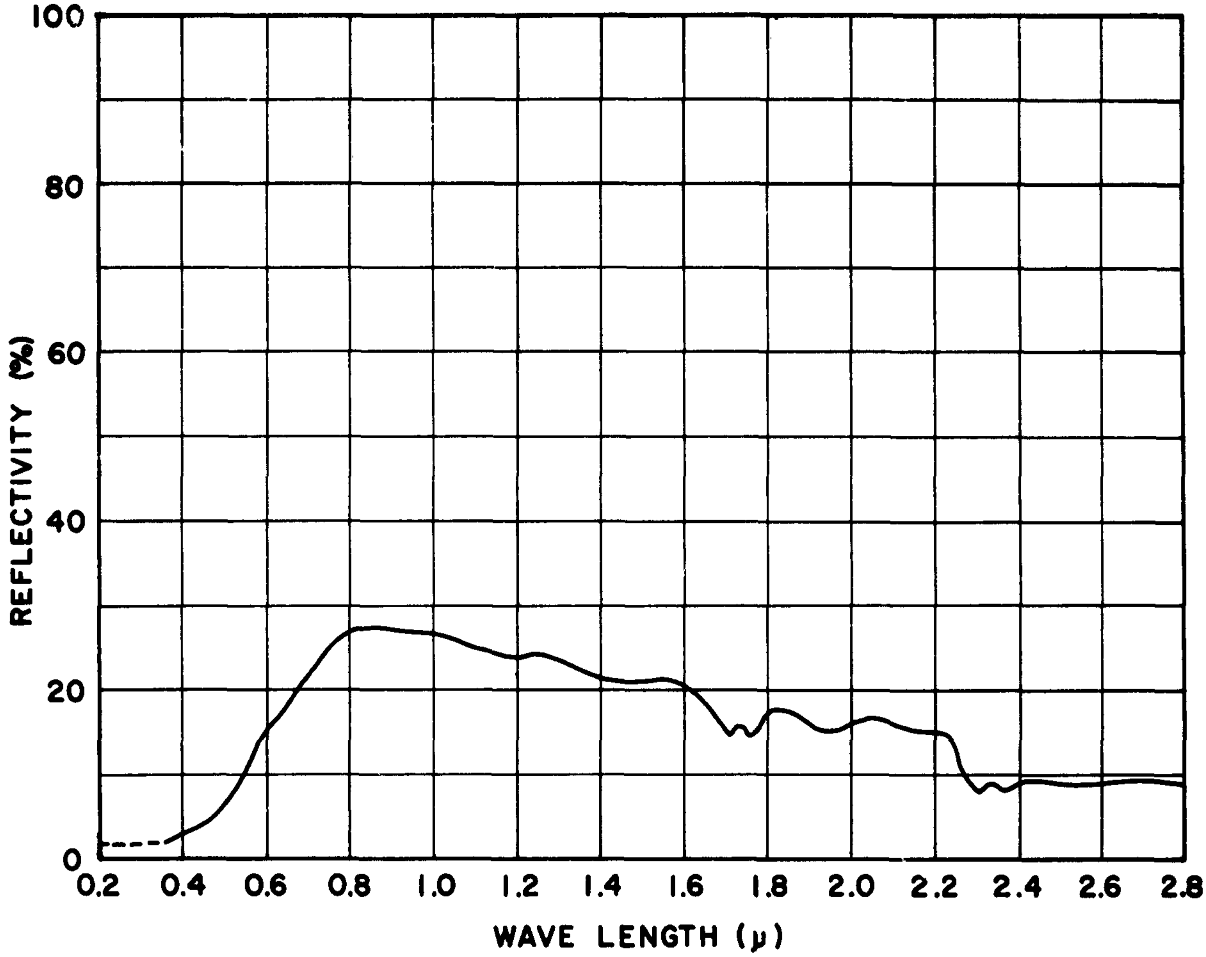
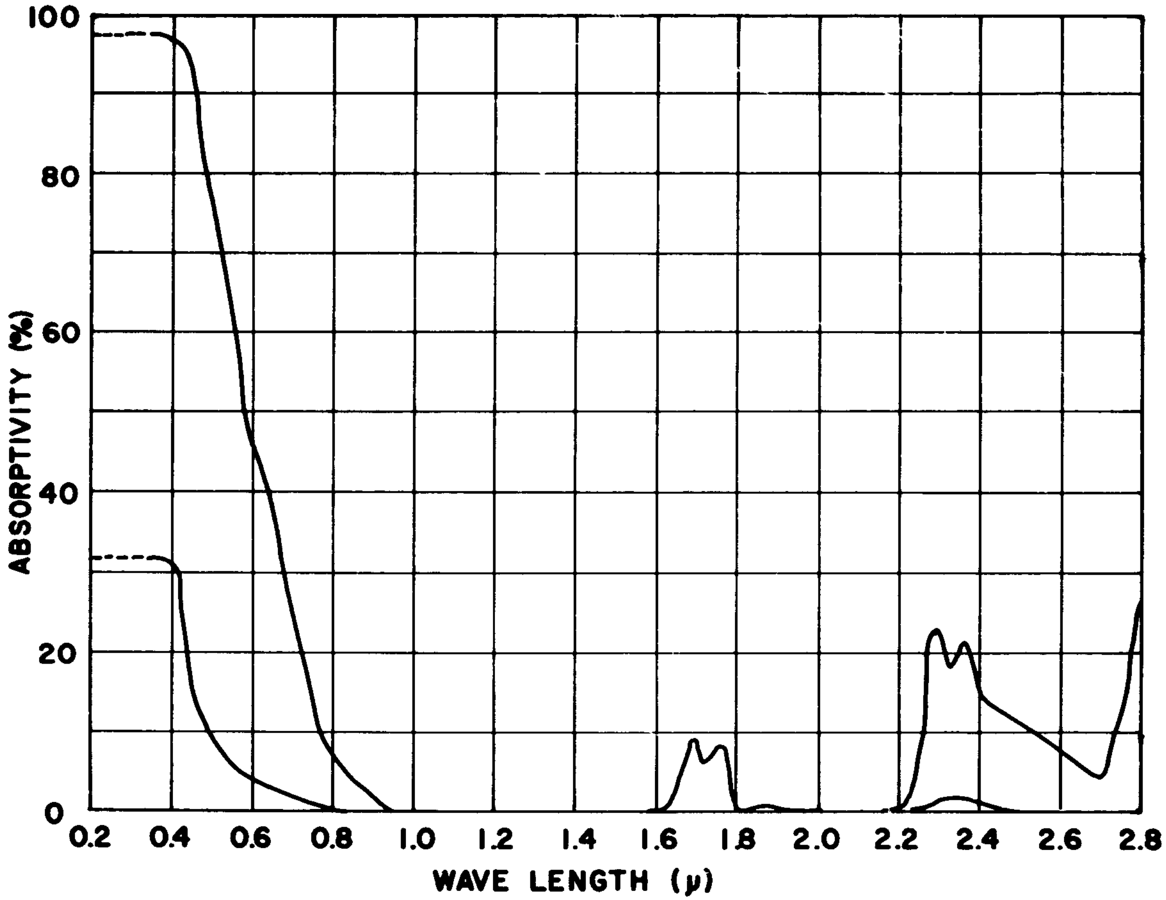


FIGURE 9

ABSORPTIVITY OF NEOPRENE FILM
(upper curve for 3.3 mils, lower curve for 0.021 mils)



(1/16 flaccid thickness corresponds to a balloon elongation of 300 percent or a balloon elevation of approximately 80,000 feet)

From Beer's law:

$$\tau_{\lambda o} = e^{-k_\lambda x_o}$$

where x_o is the thickness of the film, and k_λ is the spectral extinction coefficient. The subscript zero applies to flaccid thickness. From this

$$\tau_\lambda = e^{\frac{-kx_o}{16}}$$

gives the transmissivity of the film one sixteenth of its initial thickness.

In order to deduce the absorptivity of the film for another thickness, the following assumption about the reflectivity was made, namely, the ratio of reflectivity to absorptivity was constant for all thicknesses.

$$\frac{\alpha_\lambda}{\rho_\lambda} = \text{constant}$$

Using this relationship, the spectral absorptivity can be determined from

$$\alpha_\lambda = \frac{1 - \tau_\lambda}{1 + \frac{\rho_o}{\alpha_{\lambda o}}}$$

In this manner, the expected absorptivity of the film at 80,000 feet elevation was determined for the wavelength interval from 0.35μ to 2.8μ. These results are presented as the lower curve of Figure 9.

As no spectrophotometer with an integrating sphere for measurements in the IR region beyond 2.8μ was available, no further measurements in the IR were made at this time. The specular transmission curve for the unstretched film for the region 2.0μ to 16.0μ presented in the preceding report (see Figure 4, page 262) was used. Figure 7, when compared with this Figure in the spectral region from 2.0μ to 2.8μ where overlapping occurs, indicates a discrepancy in transmission.

The difference is undoubtedly due to diffuse transmission.

For the region from 2.8 to 16 microns, in the absence of reflectivity measurements, it was assumed that

$$\alpha_\lambda = 1 - \tau_\lambda$$

and the average values of α_λ were computed using values of τ_λ averaged over 0.1μ intervals. In this manner, assuming no infra-red reflectivity, a maximum value for absorptivity was obtained. Again, making use of Beer's law, the expected absorptivity of the neoprene film, when stretched to 1/16th its initial thickness, was deduced. This is presented in Figure 10 with the value from Figure 9 added to give the range from 0.35μ to 16μ. The absorptivity values given in Figure 10 were used in the following computations of absorption and emission by the balloon film.

3. Calculated Radiation Load

A. Absorption of Solar Radiation

The absorption of solar radiation is proportional to the integral

$$\int_0^\infty a_\lambda I_{o\lambda} d\lambda$$

As was discussed above, the variation of a_λ for the range 0.3μ to 16μ was derived from observed laboratory data. Values of $I_{o\lambda}$ were taken from the tabulated data in the Handbook of Geophysics (1960).

The computed spectral distribution of $a_\lambda I_{o\lambda}$ for a film thickness corresponding to a height of 80,000 feet and over the range of 0.2μ to 0.8μ is given in Figure 11, where it is seen that the absorbed energy is almost completely confined to the region below 0.7μ. For the range below 0.3μ (dashed curve) it was assumed that the absorptivity is constant at 0.315. Since in this range ($<0.3\mu$) the energy in the solar beam is decreasing very rapidly with decreasing wavelength,

FIGURE 10

ABSORPTIVITY OF NEOPRENE FILM FOR A BALLOON ELEVATION OF 80,000 FEET FOR SPECTRAL INTERVAL 0.35 TO 16 MICRONS

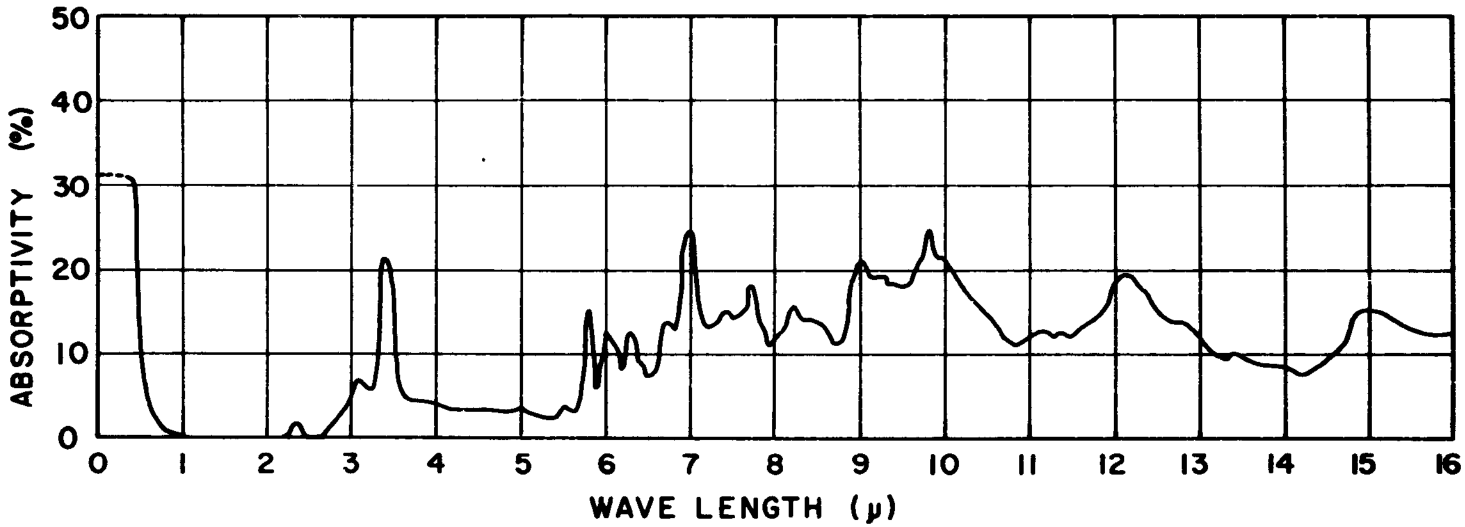
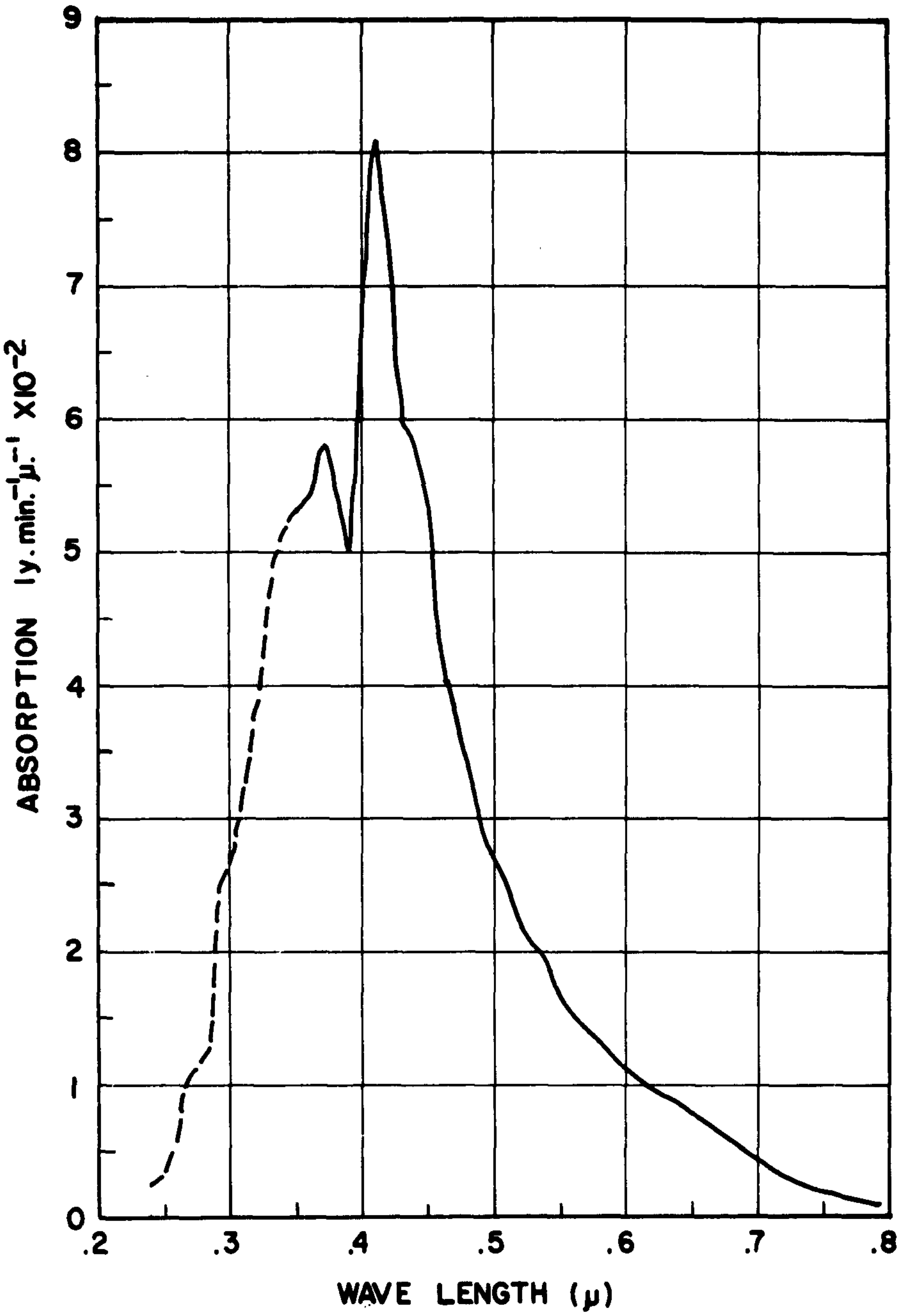


FIGURE 11
ABSORPTION OF SOLAR RADIATION BY NEOPRENE FILM
AT 80,000-FOOT ELEVATION



the total absorption depends very little on the particular value chosen for the absorptivity. It is not known what deleterious effects ultra-violet absorption might have on the neoprene film.

The total absorption under the curve shown in Figure 11 amounts to 0.140 ly min^{-1}. Since the balloon is assumed to be spherical, the incoming radiation will be constant for latitude and season (except for a small variation due to the changing distance between the earth and sun). The only variation in the solar heat load is due to the changing back scatter as a result of variable cloudiness and concentration of scattering particles. Within the accuracy of the other computations, we have assumed average air mass for conditions of clear and cloudy skies. The total absorption of solar radiation by the balloon is then

$$S\text{ (clear)} = 0.39\pi R^2 \text{ cal min}^{-1}$$

$$S\text{ (cloudy)} = 0.56\pi R^2 \text{ cal min}^{-1}$$

This represents an average heat input per unit surface area of the balloon of about 1/20 of the solar constant.

B. Infra-red Absorption

The infra-red absorption per unit area of balloon film was given as

$$\int_0^\infty a_\lambda f_\lambda d\lambda$$

The atmospheric infra-red flux for any height in the atmosphere can be computed as the solution to the basic differential equation of radiative transfer (see, for instance, London (1957)). Average values of the IR flux arriving at approximately 80,000 feet at 55°N for average winter (January) and summer (July) conditions for clear and cloudy skies have been calculated by Davis (1961). These values are shown in Figure 12 and Figure 13 for the spectral region below 36μ.

FIGURE 12

AVERAGE INFRA-RED FLUX AT 80,000-FOOT ELEVATION
55°N LAT. FOR JANUARY

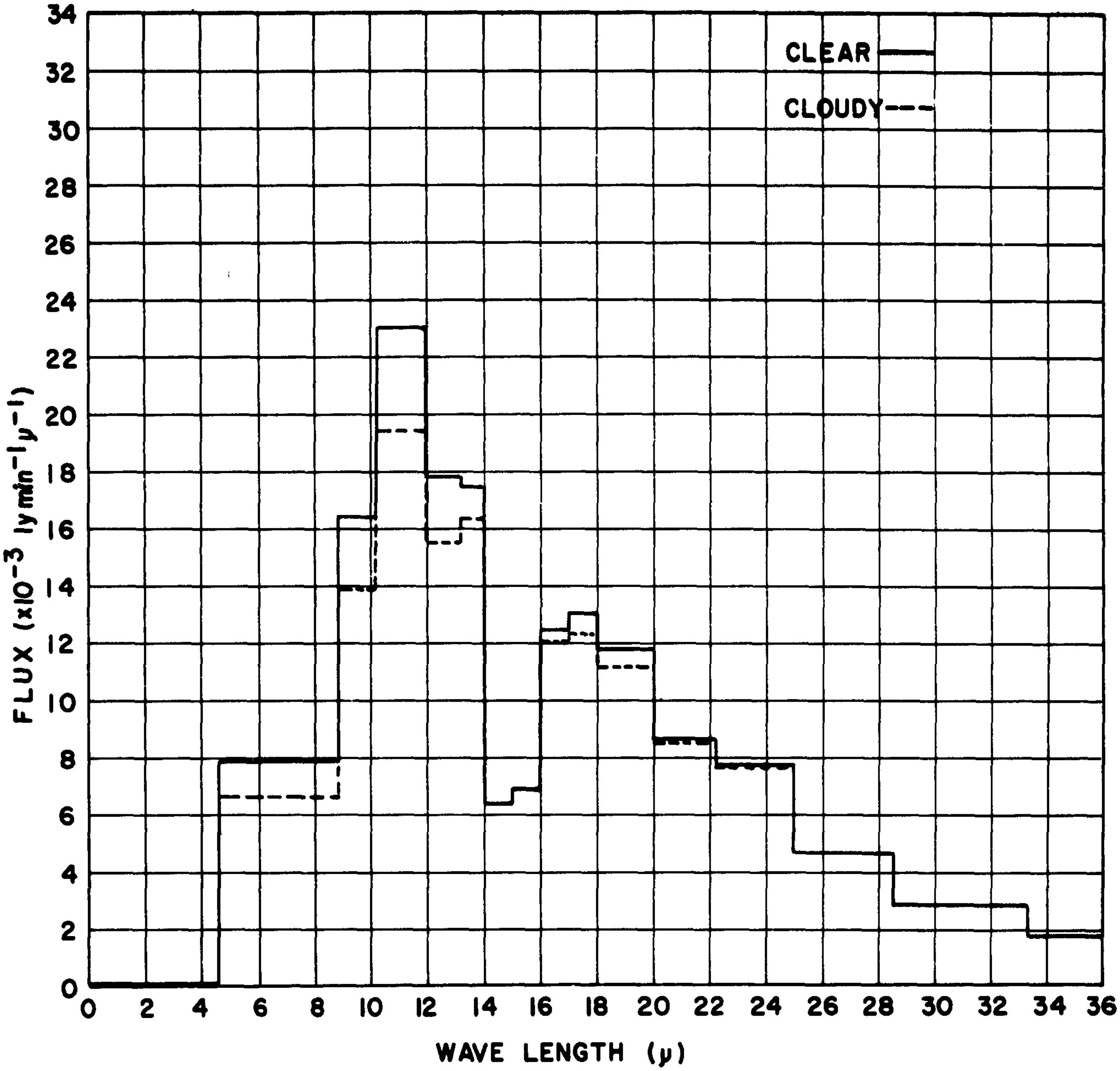
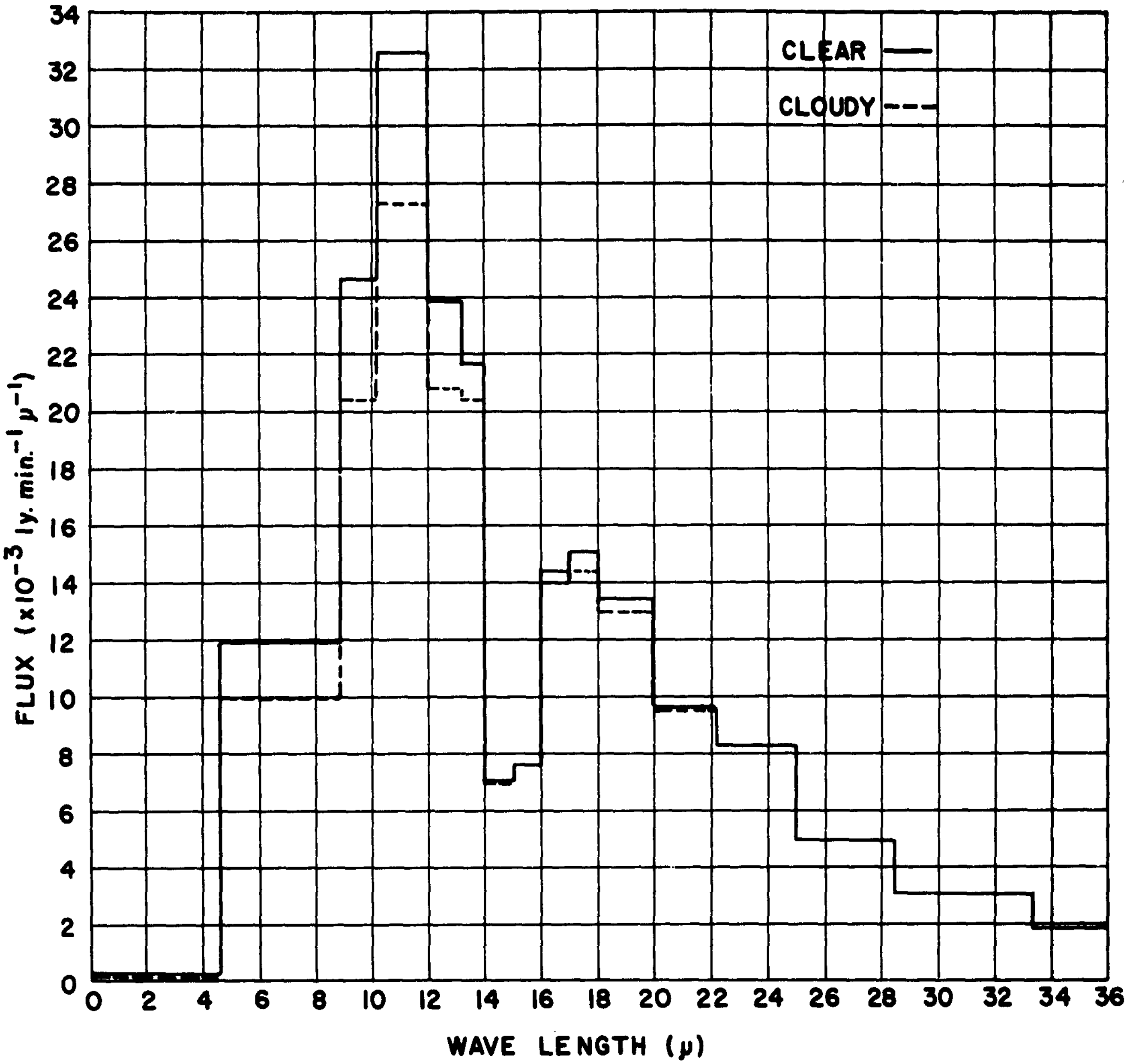


FIGURE 13

AVERAGE INFRA-RED FLUX AT 80,000-FOOT ELEVATION

55°N LAT. FOR JULY



The peak atmospheric radiation is found in the vicinity of 10μ since the maximum energy of terrestrial radiation falls in this region, and it is here that the atmosphere is quite transparent. The minimum radiation found at 15μ is due to the strong absorption band of carbon dioxide (12.5μ - 17μ). The distribution of $a_\lambda f_\lambda$ is given in Figures 14, 15, 16, and 17 for the four conditions mentioned. It is obvious from these diagrams that the absorbed energy is a maximum at about 10μ, and that it varies markedly with wavelength. The absorption for clear skies is larger than for cloudy skies (warmer radiating surface) and is distinctly larger during July than January. This latter is due to the higher surface and atmospheric temperatures.

The values of $1.5\int_0^\infty a_\lambda f_\lambda d\lambda$ were computed by numerical integration with the assumption that $a_\lambda = 0.13$ for $\lambda > 16\mu$.

The total atmospheric radiation absorbed by the neoprene film (per unit area for the four conditions is

January (clear)	=	5.9×10^{-2} cal cm^{-2} min^{-1}
January (cloudy)	=	5.4×10^{-2} cal cm^{-2} min^{-1}
July (clear)	=	7.4×10^{-2} cal cm^{-2} min^{-1}
July (cloudy)	=	6.7×10^{-2} cal cm^{-2} min^{-1}

This represents an absorption of about one-half that due to solar radiation. However, in the absence of sunlight the infra-red absorption is the only heat source for the balloon.

FIGURE 14

COMPUTED ABSORPTION OF NEOPRENE FILM AT 80,000-FOOT ELEVATION
55°N LAT. FOR JANUARY, CLEAR SKIES

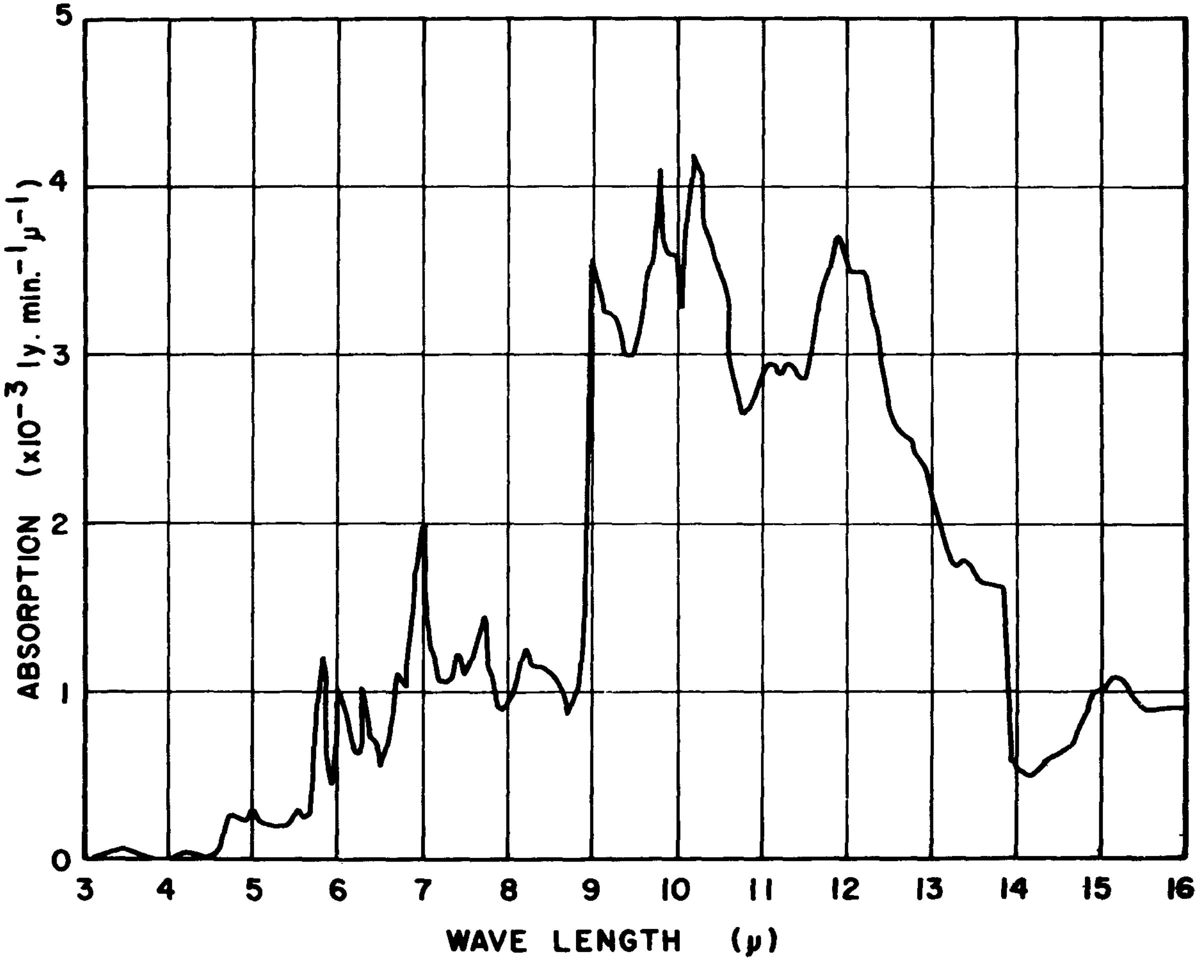


FIGURE 15

COMPUTED ABSORPTION OF NEOPRENE FILM AT 80,000-FOOT ELEVATION
55°N LAT. FOR JANUARY, CLOUDY SKIES

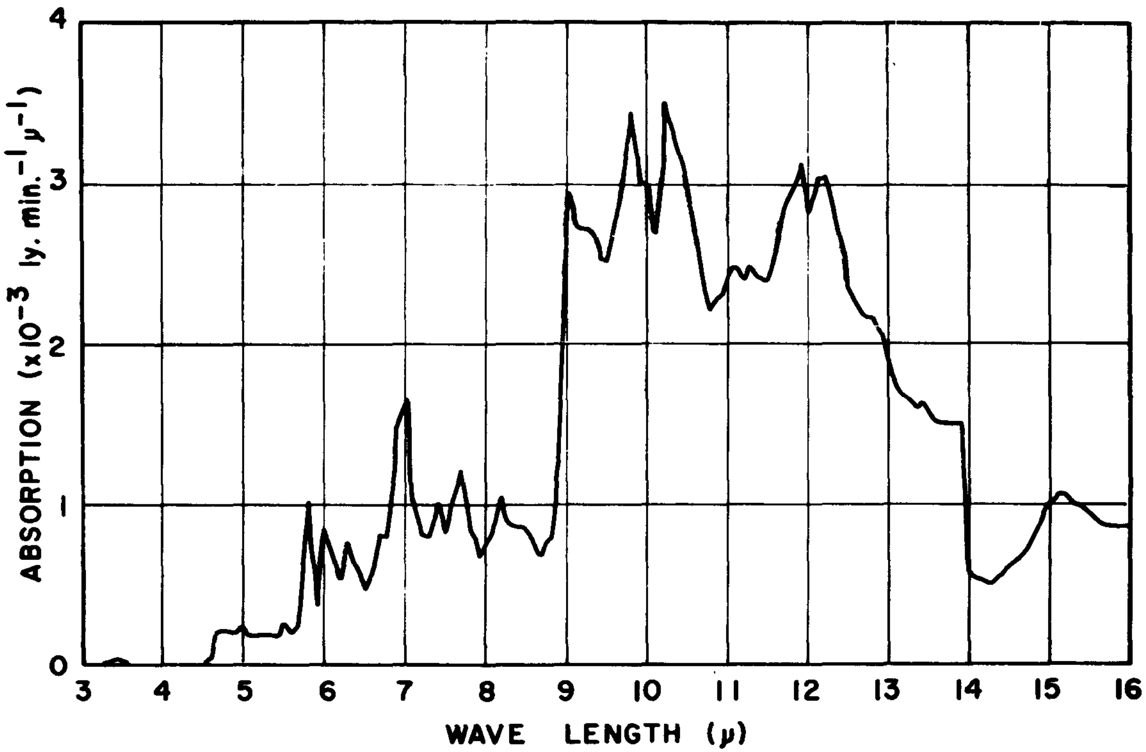


FIGURE 16

COMPUTED ABSORPTION OF NEOPRENE FILM AT 80,000-FOOT ELEVATION
55°N LAT. FOR JULY, CLEAR SKIES

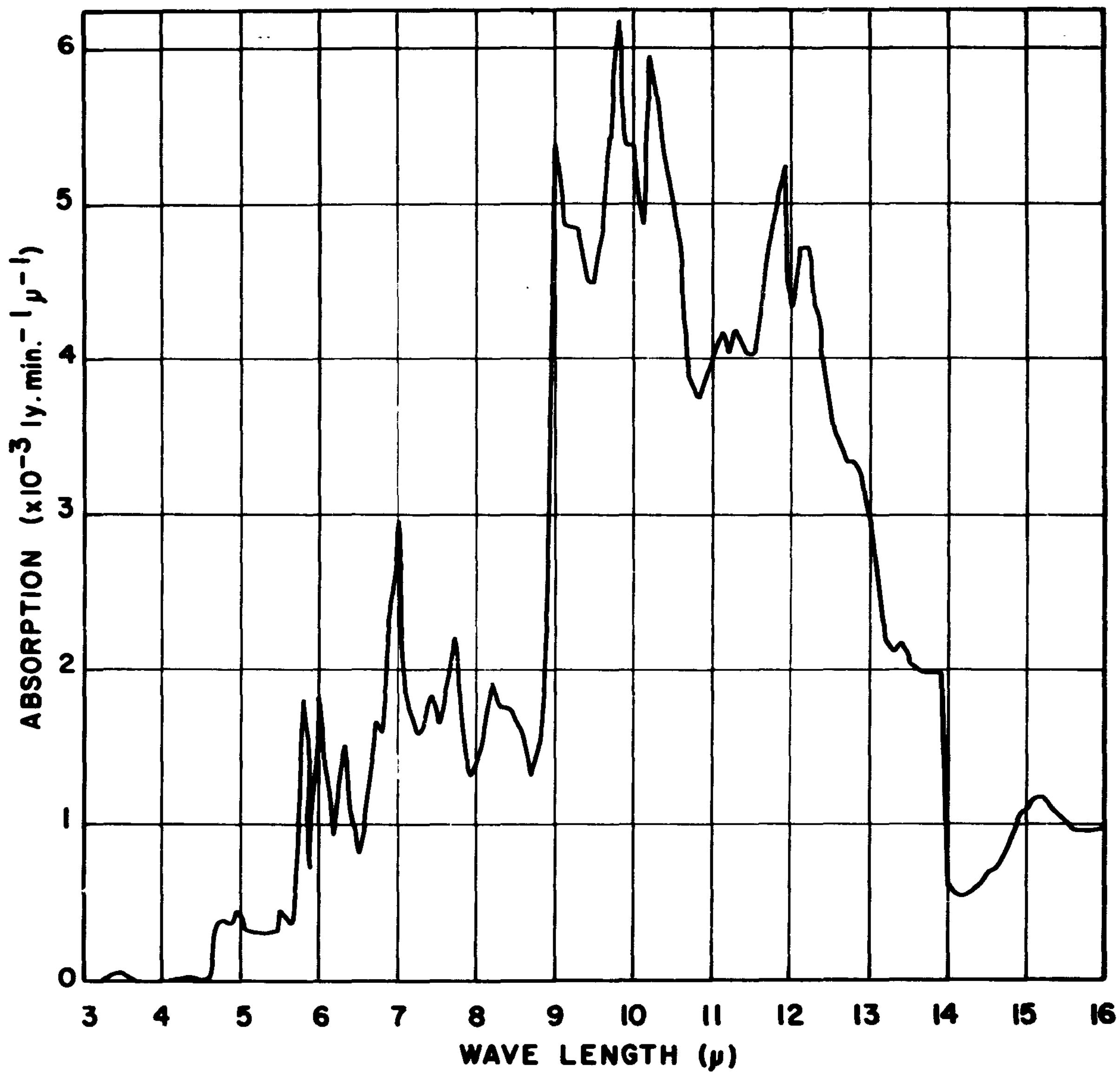
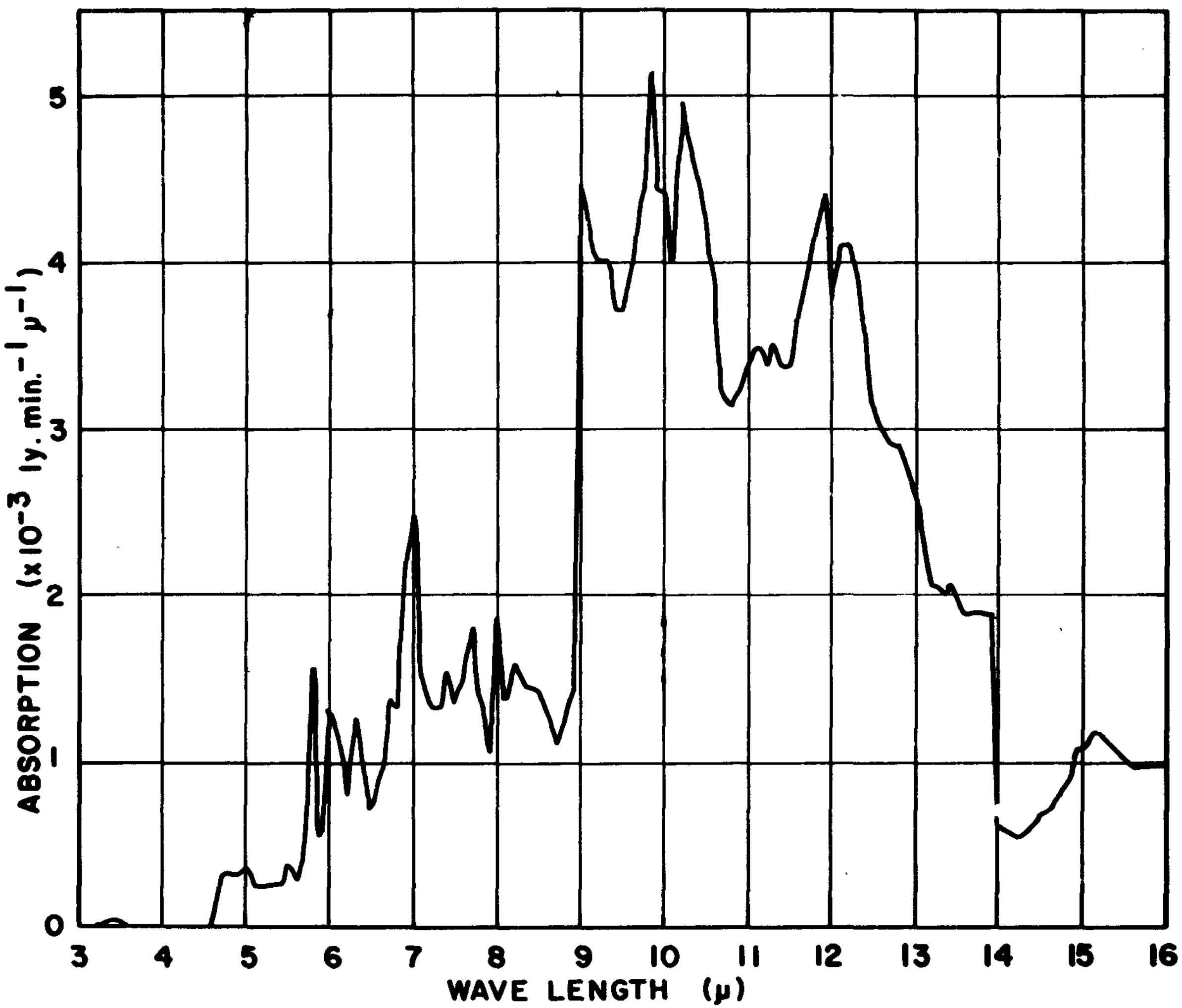


FIGURE 17

COMPUTED ABSORPTION OF NEOPRENE FILM AT 80,000-FOOT ELEVATION
55°N LAT. FOR JULY, CLOUDY SKIES



C. Radiative Equilibrium at the Balloon Surface

If we assume that the radiative time constant of the film is small, the equilibrium condition of the balloon above 25 km is determined by equating the total heat gain to the total loss. That is

$$S + A = E$$

From equations (1), (2), and (3) this becomes

daytime clear: $$2.8\pi R^2\int_0^\infty a_\lambda I_{o\lambda}d\lambda + 6\pi R^2\int_0^\infty a_\lambda f_\lambda d\lambda = 12\pi R^2\int_0^\infty a_\lambda f_{b\lambda}(T_B)d\lambda \quad (4a)$$

daytime cloudy: $$4\pi R^2\int_0^\infty a_\lambda I_{o\lambda}d\lambda + 6\pi R^2\int_0^\infty a_\lambda f_\lambda d\lambda = 12\pi R^2\int_0^\infty a_\lambda f_{b\lambda}(T_B)d\lambda \quad (4b)$$

night time: $$6\pi R^2\int_0^\infty a_\lambda f_\lambda d\lambda = 12\pi R^2\int_0^\infty a_\lambda f_{b\lambda}(T_B)d\lambda \quad (4c)$$

It is noted that in equations (4a), (4b), and (4c) the emission term contains the non-linear expression $\int_0^\infty a_\lambda f_{b\lambda}(T_B)d\lambda$. Since the variation of $f_{b\lambda}$ depends only on temperature, it is possible to solve the above equations for an equilibrium temperature by iterative procedures since a_λ is assumed known. The computation, however, is tedious if many spectral intervals are used. The assumption was made instead that a_λ is constant over the spectrum. The gray body emission is then $12\pi R^2(\bar{a}_\lambda)\sigma T_B^4$ where σT_B^4 represents the total black body emission at the balloon film temperature.

Although this procedure introduces some error to the final results, it turns out to be not as serious as was the assumption of a_λ = constant in the integral $\int_0^\infty a_\lambda f_\lambda d\lambda$.

It can be seen from the results of the laboratory data that the average value of a_λ over the spectrum is approximately 0.13 for a height equivalent to 80,000 feet. Equations (4a), (4b), and (4c) then become

daytime clear: $2.8\int_0^\infty a_\lambda I_{o\lambda} d\lambda + 6\int_0^\infty a_\lambda f_\lambda d\lambda = 1.4\sigma T_B^4$

daytime cloudy: $4\int_0^\infty a_\lambda I_{o\lambda} d\lambda + 6\int_0^\infty a_\lambda f_\lambda d\lambda = 1.4\sigma T_B^4$

night time: $6\int_0^\infty a_\lambda f_\lambda d\lambda = 1.4\sigma T_B^4$

If we now substitute the values for $\int_0^\infty a_\lambda I_{o\lambda} d\lambda$ and $\int_0^\infty a_\lambda f_\lambda d\lambda$ as given above for clear and cloudy skies, January and July, we have:

TABLE 175

RADIATIVE EQUILIBRIUM TEMPERATURE OF BALLOON (T_B) AT 80,000 FEET

			T_B (°C)
Daytime	January	clear	+1
	January	cloudy	+13
	July	clear	+7
	July	cloudy	+20
Night time	January	clear	-58
	January	cloudy	-68
	July	clear	-48
	July	cloudy	-54

We see that during the daytime the equilibrium temperatures vary from +1°C to +20°C, with the temperatures being slightly lower during January as compared to July. The equilibrium balloon temperatures are higher when there are clouds present because of the increased solar radiation reflected from below. During the night the equilibrium temperatures vary from -68°C to -48°C, and again are slightly lower during winter. These temperatures, however, are higher for

clear than for cloudy skies, since the bulk of the atmospheric radiation would come from a lower, therefore warmer, region.

4. Comparison with Balloon Flight Data

Observations were taken by the Signal Corps of temperatures both inside and outside of test balloons while in flight. These flights were all made at Fort Monmouth, New Jersey, and in some cases reached 100,000 feet. In all, there were approximately one hundred flights covering a period of about two years with more of the flights during the summer months than any other season. The observations were for day and night flights during both clear and cloudy sky conditions. Sky conditions, when classified as cloudy, were not broken down into cloud types. Some runs were taken with CO_2 introduced along with the H_2.

During the flights, thermistor elements were used to measure temperatures inside the balloon about six inches from the top and bottom, and the free air temperature outside the balloon. The temperature data were grouped according to day and night, clear and cloudy conditions. The mean vertical distribution of the air temperature for each subgroup is shown in Table 176.

TABLE 176

MEAN VERTICAL DISTRIBUTION OF THE AIR TEMPERATURE (°C) AT FT. MONMOUTH

Elevation ($\times 10^4$ ft.)	1	2	3	4	5	6	7	8	9	10
Day Clear	0	-18.4	-39.5	-52.9	-60.5	-58.8	-55.2	-52.3	-48.0	-45.0
Day Cloudy	+4.7	-13.1	-34.1	-53.8	-61.0	-58.0	-54.2	-51.8	-48.6	-45.1
Night Clear	+1.8	-15.7	-39.8	-57.2	-61.0	-58.3	-54.3	-54.7	-49.2	-50.8
Night Cloudy	-2.9	-20.9	-40.8	-55.1	-59.8	-59.6	-56.5	-54.5	-50.3	-43.5
Annual Mean	+1.4	-16.6	-38.1	-54.8	-60.8	-58.7	-55.0	-53.1	-49.0	-45.5

It should be noted that the annual mean for all the data as shown on line 5 of the table was computed from the original data and involves some bias since the number of observations within each subgroup and elevation is not the same. There is very little difference in the data between clear and cloudy skies. The small apparent diurnal variation probably results from a sampling bias.

In the upper troposphere and lower stratosphere, both theory (London (1957)) and observations (Kochanski (1955), Handbook of Geophysics (1960)) indicate that there should be small diurnal and seasonal temperature variations at these latitudes. The mean vertical distribution of air temperature for all the data is shown in Figure 18.

Since the individual temperature data varied a great deal from observation to observation, only temperature differences as noted below were used for the analyses. The statistics studied were the mean and standard deviation for each height and subgroup. These were computed and are shown in Figures 19, 20, 21, and 22..

It should be pointed out at the start that the data are relatively few, and the statistics can only be relied upon in qualitative fashion. The variance of the data indicates that although there is a consistent difference between clear and cloudy conditions, this difference cannot be treated as statistically significant. In the one case where there was sufficient data (T_B-T_A) for daytime cloudy conditions, the variance was reduced somewhat by considering the summer season only. (See, for instance, Table 177.)

FIGURE 18

MEAN VERTICAL AIR TEMPERATURE DISTRIBUTION

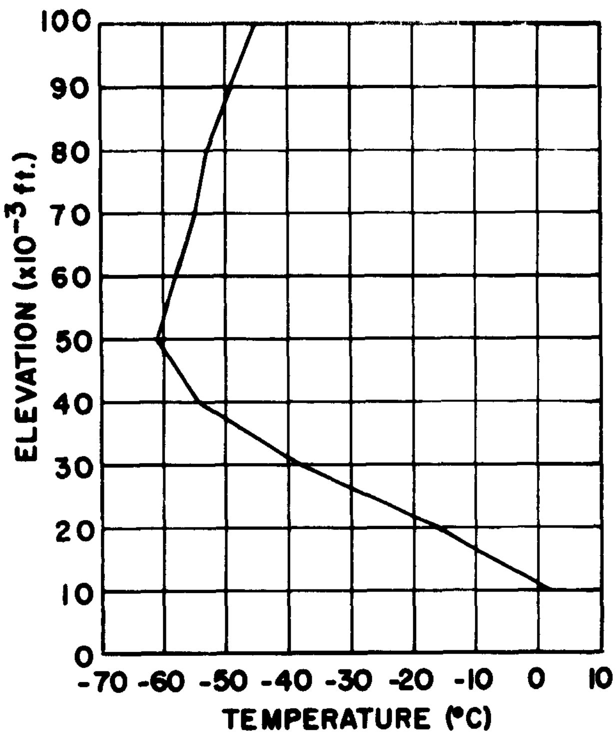


FIGURE 19

DIFFERENCE BETWEEN TEMPERATURE INSIDE BALLOON AT BOTTOM (T_B) AND TOP (T_T) FOR DAYTIME CLEAR AND CLOUDY CONDITIONS

(Horizontal lines represent ± one standard deviation)

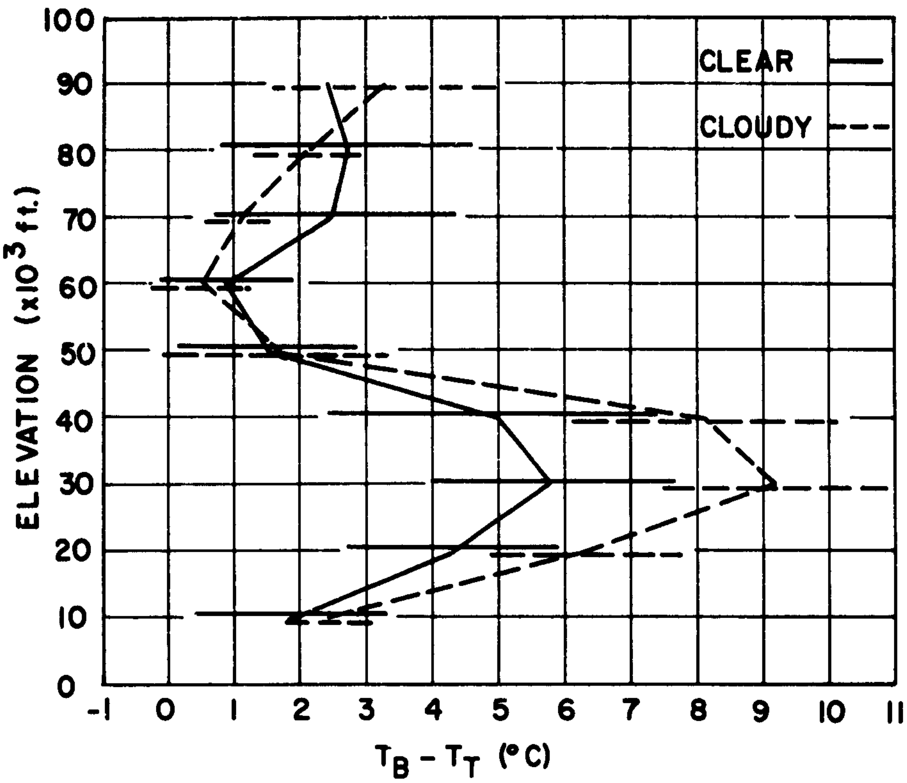


FIGURE 20

DIFFERENCE BETWEEN TEMPERATURE INSIDE BALLOON AT BOTTOM (T_B) AND TOP (T_T) FOR NIGHT-TIME CLEAR AND CLOUDY CONDITIONS

(Horizontal lines represent ± one standard deviation)

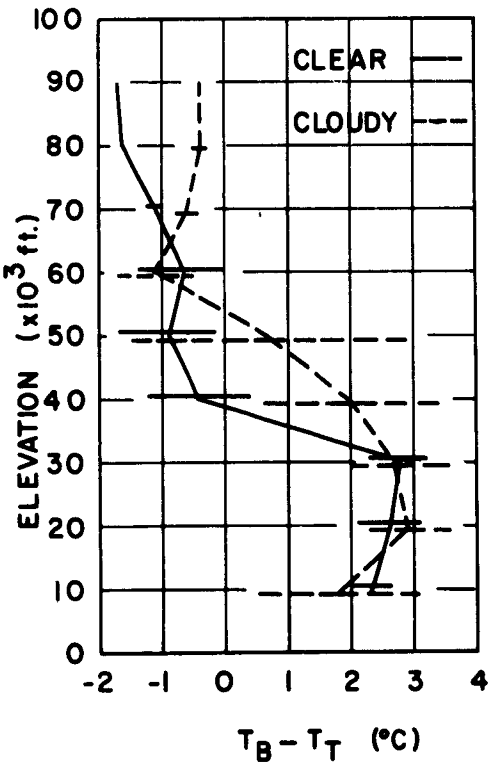


FIGURE 21

DIFFERENCE BETWEEN TEMPERATURE INSIDE BALLOON AT BOTTOM (T_B) AND THE AIR (T_A) FOR DAYTIME CLEAR AND CLOUDY CONDITIONS

(Horizontal lines represent ± one standard deviation)

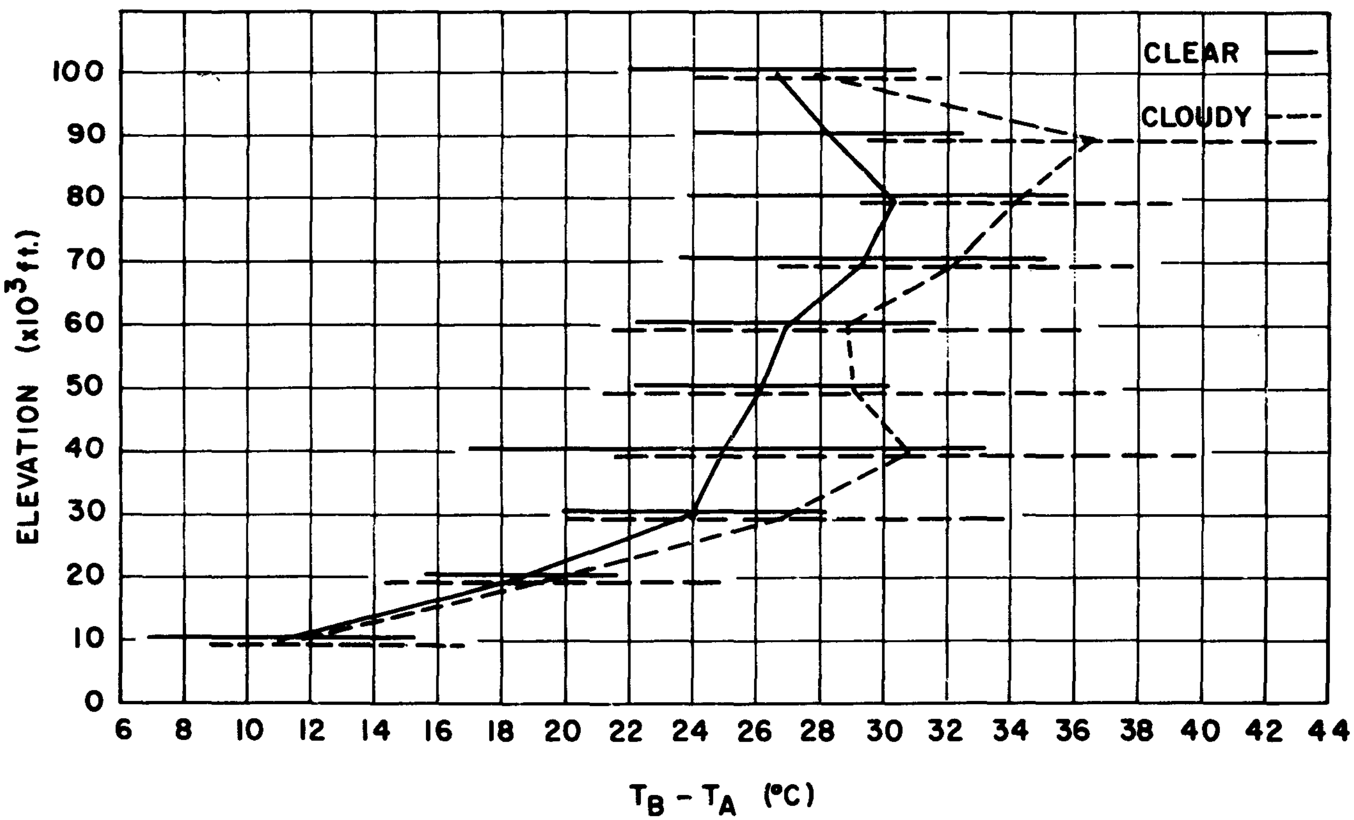


FIGURE 22

DIFFERENCE BETWEEN TEMPERATURE INSIDE BALLOON AT BOTTOM (T_B) AND THE AIR (T_A) FOR NIGHT-TIME CLEAR AND CLOUDY CONDITIONS

(Horizontal lines represent ± one standard deviation)

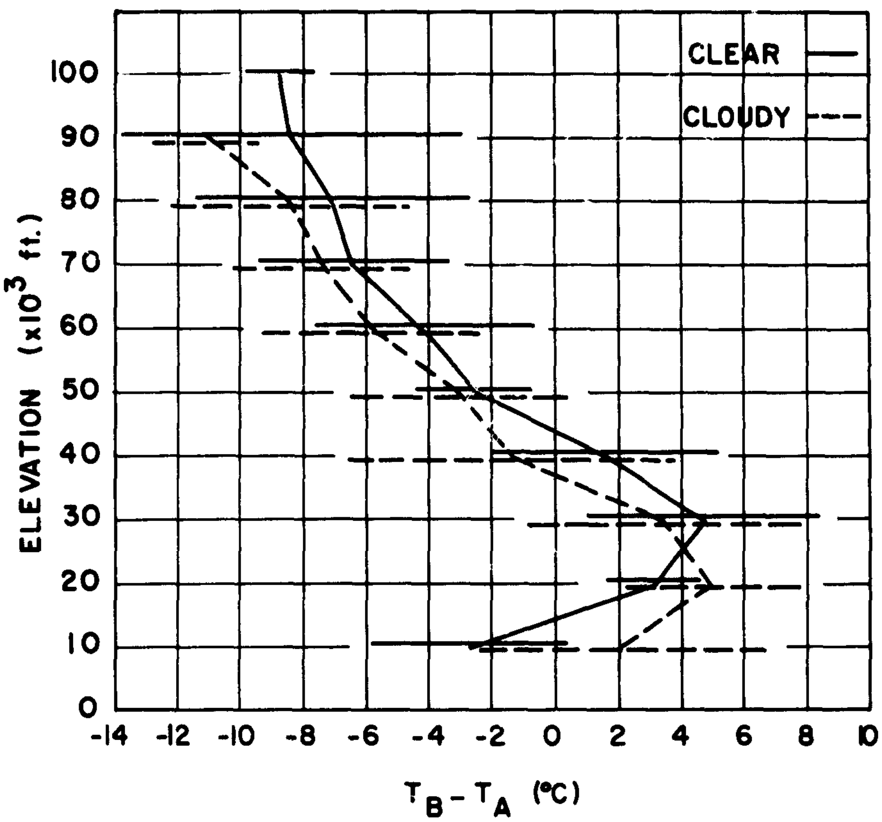


TABLE 177

COMPARISON OF TEMPERATURE DIFFERENCE (T_B-T_A) (°C) BETWEEN ANNUAL AND SUMMER DAYTIME CLOUDY CONDITIONS

Elevation (x 10^4 ft.)	1	2	3	4	5	6	7	8	9	10
Annual mean	11.7	19.5	26.8	30.7	29.0	28.8	32.2	34.2	36.4	27.8
Summer mean	12.4	21.1	28.9	34.1	32.4	31.1	33.7	35.4	35.6	33.0
Annual σ	4.9	5.3	6.8	9.2	7.9	7.4	5.5	4.9	7.1	3.9
Summer σ	4.8	3.4	3.8	6.0	4.8	5.4	5.6	3.4	5.3	1 obs.

In the discussion that follows:

T_A refers to the temperature in the free air at the balloon level

T_B refers to the temperature inside the balloon about 6 inches from the bottom

T_T refers to the temperature inside the balloon about 6 inches from the top

The curves plotted in Figures 19, 20, 21, and 22 show the mean values of the data with the horizontal bar indicating ± one sigma about the mean.

Figures 19 and 20 represent values for (T_B-T_T), that is, the temperature difference between top and bottom inside the balloon.

The daytime observations show positive values (i.e., $T_B > T_T$) at all levels. The maximum value for (T_B-T_T) occurs at about 30,000 feet and is about 6°C and 9°C for clear and cloudy skies, respectively. At about 60,000 feet there is a minimum of (T_B-T_T), about 1°C, and then a slight rise. The standard deviations for these values, as well as those discussed below, indicate that whereas the trends and the sign of the reported temperature differences are probably reliable (representative) the exact quoted values are not.

At night, clear and cloudy conditions are again quite similar and the temperature difference pattern is at least qualitatively the same as described for the daytime flights. During the night $T_B > T_T$ up to about 40,000 to 50,000 feet, above which $T_B < T_T$. The major difference between day and night conditions is that the temperature differences are quite small during the night (about one-third of those during the day), and at levels above 40,000 feet the gas within the balloon seems to remain nearly isothermal.

As the balloon rises through the troposphere it will continuously be ventilated by the cold air above. In the stratosphere the lapse rate is very small and the ventilation effect will be a minimum. It is important to note that the assumption made in the theoretical discussion above that the gas was at a uniform temperature at the level of 80,000 feet is apparently well satisfied.

Comparison of Figures 19 and 20 shows that (T_B-T_A) is larger during the day as compared to night. It is not clear why this should be except possibly for the addition of upward diffuse reflection acting on the bottom of the balloon. This latter explanation is consistent with the fact that in the region where (T_B-T_T) is largest, $\sim$30,000 feet, the temperature difference for cloudy skies is larger than for clear skies. As was pointed out in Section 3 above, upward diffuse reflection is more than doubled for cloudy as compared to clear skies.

Temperature differences between the balloon and the air (T_B-T_A) are shown in Figures 21 and 22. In all cases the values of (T_B-T_A) are much larger than (T_B-T_T) indicating that whatever ventilating effect is present it is much smaller than the radiative effect. Since the diurnal temperature change of the free air at these levels is extremely small ($<$ 2°C amplitude), the temperature difference must indicate differences of the heat load on the balloon.

In the daytime, Figure 21 shows that (T_B-T_A) is positive throughout (up to 100,000 feet), increasing from about 10°C at 10,000 feet to a maximum of 30-35°C at about 80,000-90,000 feet. Above this level presumably the air temperature increases faster than the balloon temperature. At all levels the balloon seems to be warmer with cloudy than with clear skies.

The night-time values of (T_B-T_A) are given in Figure 22 where it is seen that $T_B > T_A$ in lower layers (up to about 40,000 feet) and $T_B < T_A$ above. There are indications also that at least about 30,000 feet (T_B-T_A) is slightly larger for cloudy conditions than for clear skies.

5. Conclusions

There is obviously a large difference in temperature of the balloon between day and night, and the effect of clouds is to warm the balloon during the day and cool it slightly at night.

As was pointed out above, the data could not be separated into seasonal values. We have already seen, however, that the theoretical temperature values do not vary appreciably with season at this altitude. We can, therefore, combine the January and July radiative equilibrium balloon temperatures as given in Table 175 and compare them with the observed balloon temperatures at 80,000 feet. These temperatures are given in Table 178.

It can be seen from this table that qualitatively there is excellent agreement between the calculated and observed balloon temperatures. The large day- and night-temperature variation is clearly seen to result from the solar radiation load on the balloon where, as expected, the balloon is warmer for cloudy as compared to clear conditions. During the night, the results also indicate that cloud radiation will produce a lower balloon temperature than would be the

TABLE 178

COMPARISON OF RADIATIVE EQUILIBRIUM AND OBSERVED BALLOON TEMPERATURE

	Calculated (°C)	Observed (°C)
Day clear	+ 4	-23
Day cloudy	+16.5	-19
Night clear	-53	-60
Night cloudy	-61	-61.5

case with clear skies. This results from the fact that the radiating surface itself is at a lower temperature at the cloud tops than at the earth's surface.

The difference between the observed and calculated temperature values results from some of the assumptions made in the theoretical calculations and the extremely large variance of the observational data. The apparent quantitative agreement between observed and computed value for night, cloudy skies is undoubtedly fortuitous.

References

Davis, P., 1961: Radiation Flux in the Atmosphere. Department of Meteorology and Oceanography, New York University.

Johnson, F. S., 1954: The Solar Constant, J. of Meteor., II, 431-439.

Kochanski, A., 1955: Cross Section of the Mean Zonal Flow and Temperature along 80°W, J. of Meteor., 12, 95-106.

London, J., 1957: A Study of the Atmospheric Heat Balance. Final Report. Contract No. AF 19(122)-165. Research Division, College of Engineering, New York University.

Möller, F., 1959: Measurement of Atmospheric Radiation by a Black Ball, J. of Meteor., 16, 87-90.

United States Air Force, 1960: Handbook of Geophysics, The MacMillan Company, 2-39.

FACTUAL DATA (continued)

TASK B. Phase 3 (continued)

Spectral Characteristics of Colored Neoprene Film

Measurements of the spectral characteristics of neoprene film of various thicknesses and colors were made for the near infra-red region. A Beckman Instruments IR-5A infra-red spectrophotometer with NaCl prism was used to measure the transmittance in the wavelength interval from 2 to 16 microns. Samples of white, red, and black neoprene were stretched over sample holders to give thicknesses ranging from flaccid (3.3 mils) to 0.3 mils. The results of these measurements are summarized in Figures 23, 24, 25.

Figure 23 (top) shows the percent transmittance of three thicknesses of white neoprene film, namely, 1.4, 0.83, and 0.5 mils. These three curves illustrate the increasing transmittance as the thickness of the film is decreased. Also, in the range of 2 to 5 microns, the effect of scattering becomes less pronounced as the thickness is decreased.

Figure 23 (center) shows the percent reflectance of the same three samples. For these measurements, a 30° incidence reflectance attachment to the IR-5A was used. This measure of the specular reflection at 30° does not include all reflected energy since there is also diffuse reflection, particularly in the region 2 to 5 microns. However, since no spectrophotometer is yet available which will give the total reflectance in the infra-red, these measurements may be taken to give a qualitative indication of the minimum reflection over the spectral interval 2 to 16 microns.

The curve for 1.4 mils thickness shows very low reflection over the whole range with a small maximum of about 3% at 9 to 10 microns and beyond 13 microns. The thinner films indicate an increasing amount of reflection averaging about 4% for 0.83 mils and 5% for 0.5 mils.

Another interesting feature of these curves is the marked interference pattern produced by reflection from the top and bottom surfaces of the film. These interference patterns can be used to determine the thickness of the films with great accuracy. The formula for this determination is

$$d = \frac{n}{2}\left(\frac{l_2 \cdot l_1}{l_2 - l_1}\right)$$

where n is the number of waves; l_2 and l_1 are the wavelengths in units of length; d is the thickness of the film in the same units.

Figure 23 (bottom) indicates the absorptivity of the same three samples. The absorptivity was computed according to

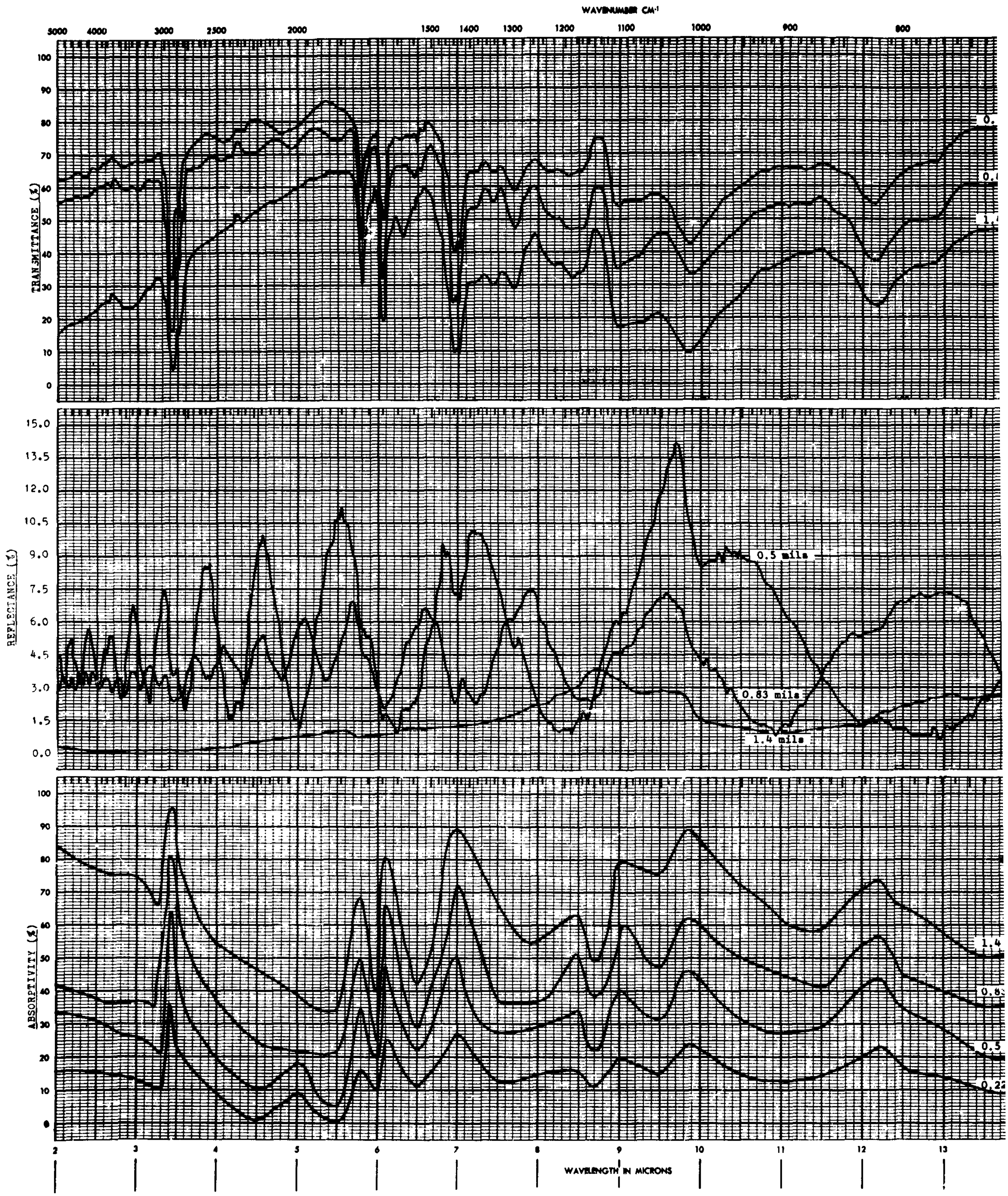
$$A\% - 100 - T\% - R\%$$

where A is absorptivity; T is transmissivity; R is reflectivity.

FIGURE 23

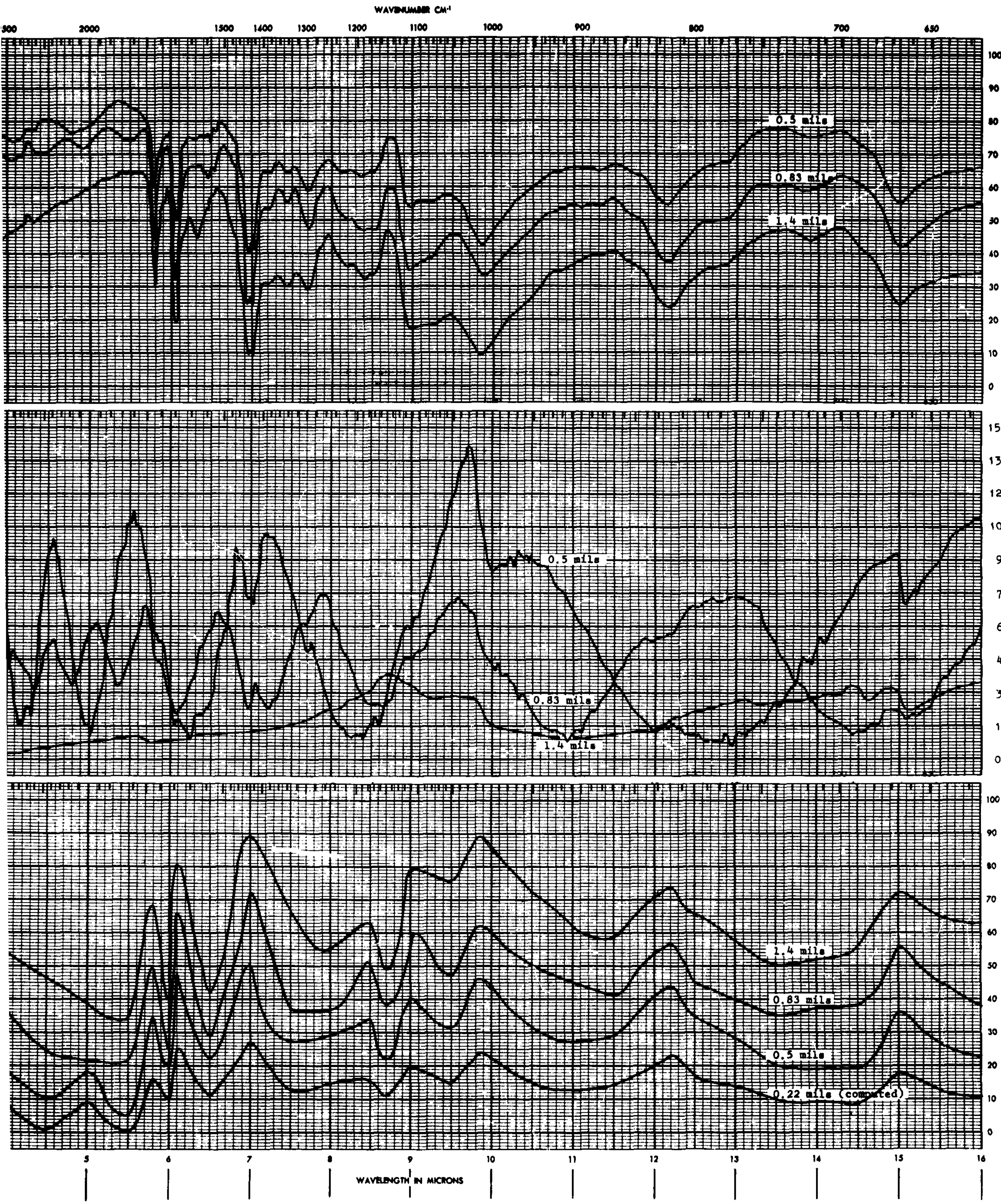
SPECTRAL TRANSMITTANCE, REFLECTANCE, AND ABSORPTIVITY IN PERCENT FOR WHITE NEOPRENE FILMS OF VARIOUS THICKNESSES

SPECTRAL TRANSMITTANCE, REFLECTANCE, AND ABSORPTIVITY IN PERCENT FOR WHITE NEOPRENE FILMS OF VARIOUS THICKNESSES



1

SPECTRAL TRANSMITTANCE, REFLECTANCE, AND ABSORPTIVITY IN PERCENT FOR WHITE NEOPRENE FILMS OF VARIOUS THICKNESSES

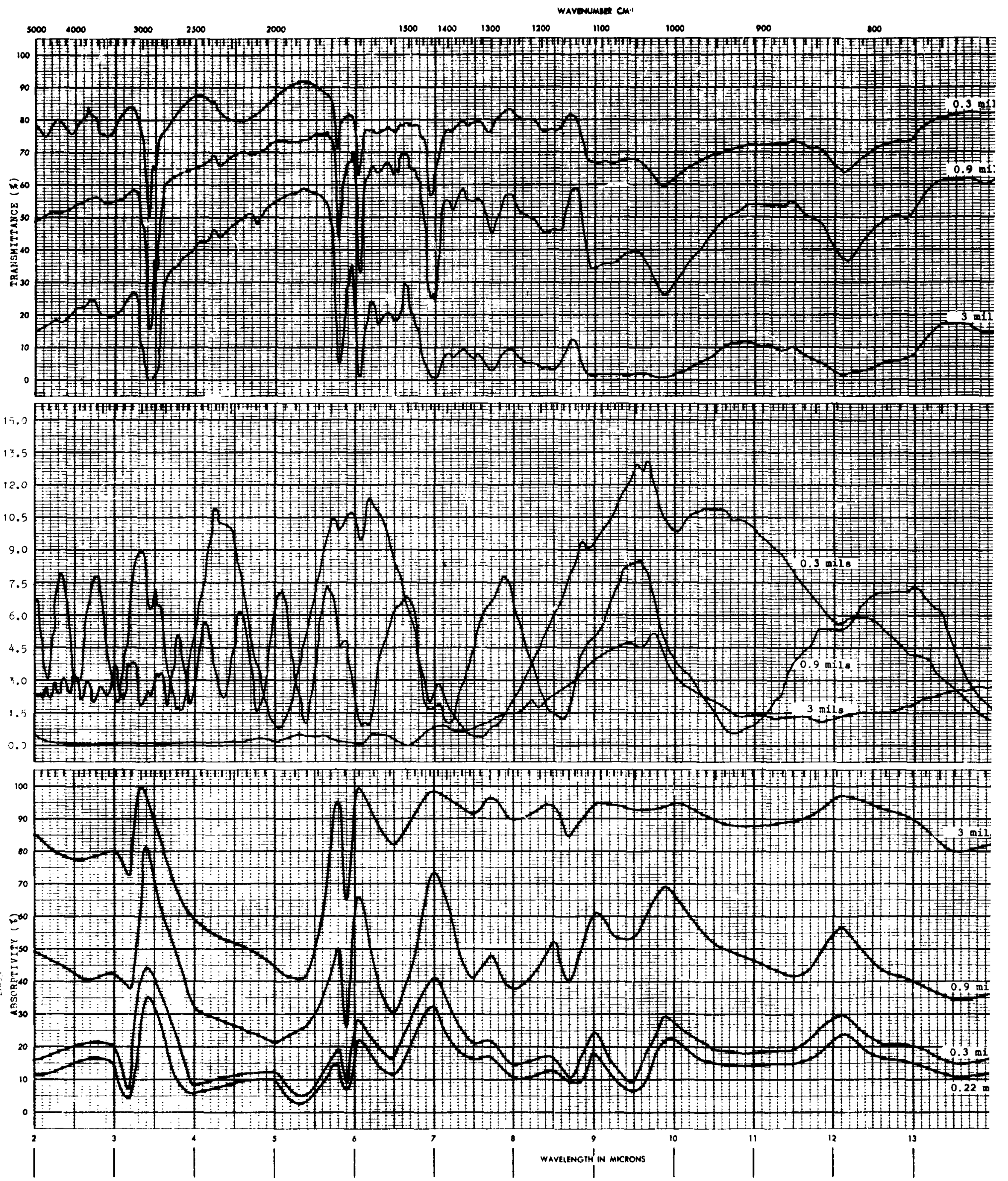


2

FIGURE 24

SPECTRAL TRANSMITTANCE, REFLECTANCE, AND ABSORPTIVITY IN PERCENT FOR RED NEOPRENE FILMS OF VARIOUS THICKNESSES

SPECTRAL TRANSMITTANCE, REFLECTANCE, AND ABSORPTIVITY IN PERCENT FOR RED NEOPRENE FILMS OF VARIOUS THICKNESSES



1

SPECTRAL TRANSMITTANCE, REFLECTANCE, AND ABSORPTIVITY IN PERCENT FOR RED NEOPRENE FILMS OF VARIOUS THICKNESSES

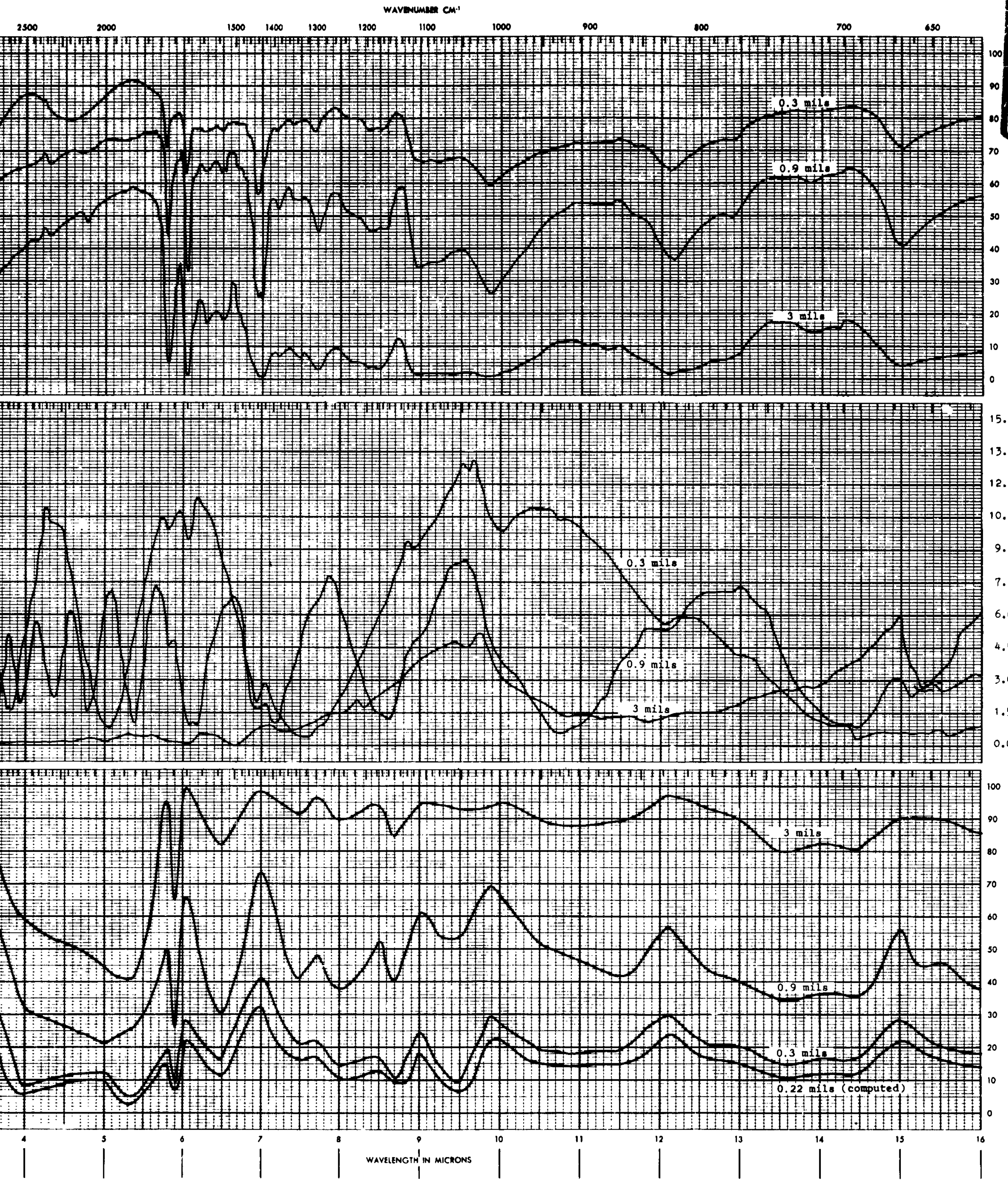
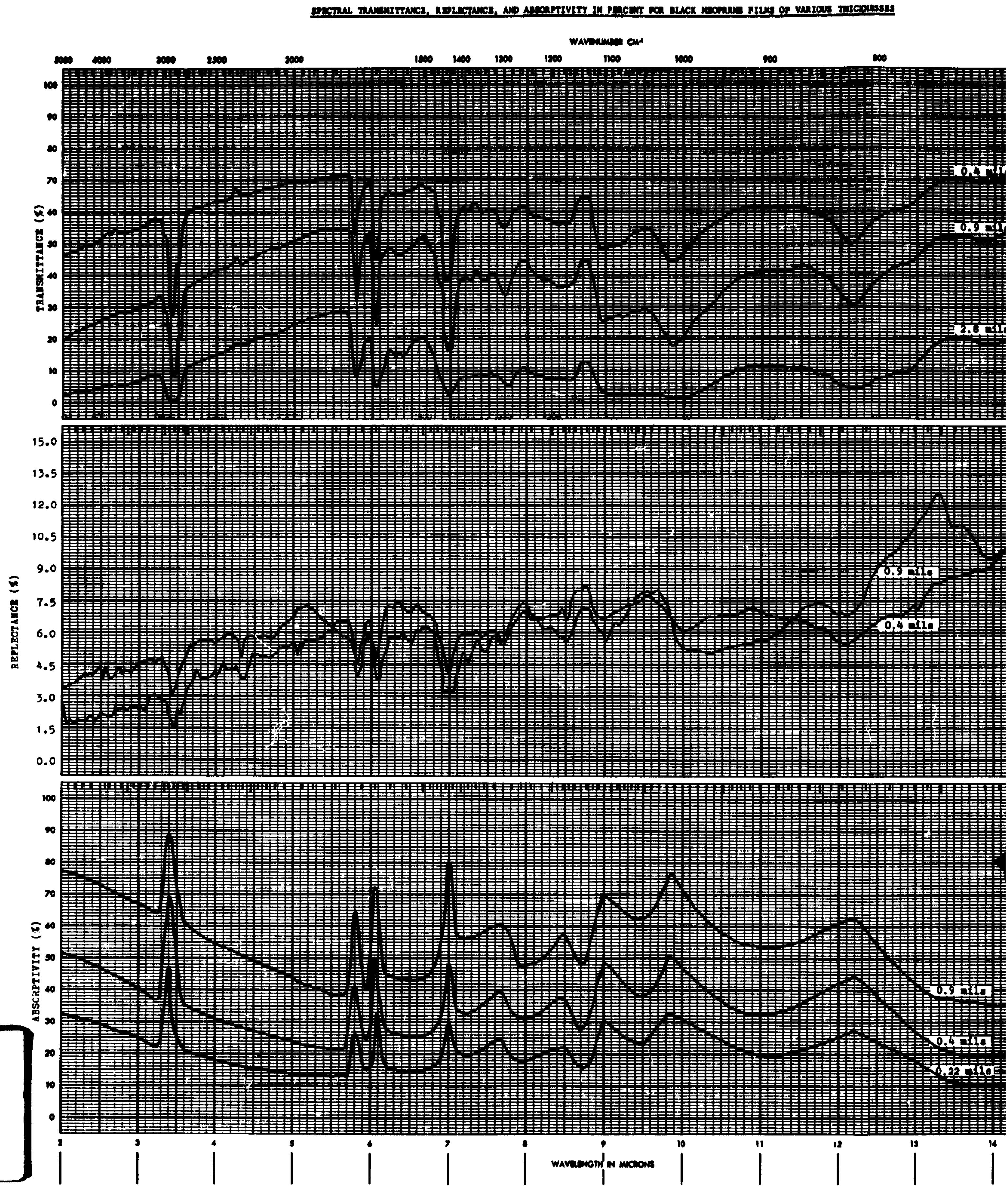
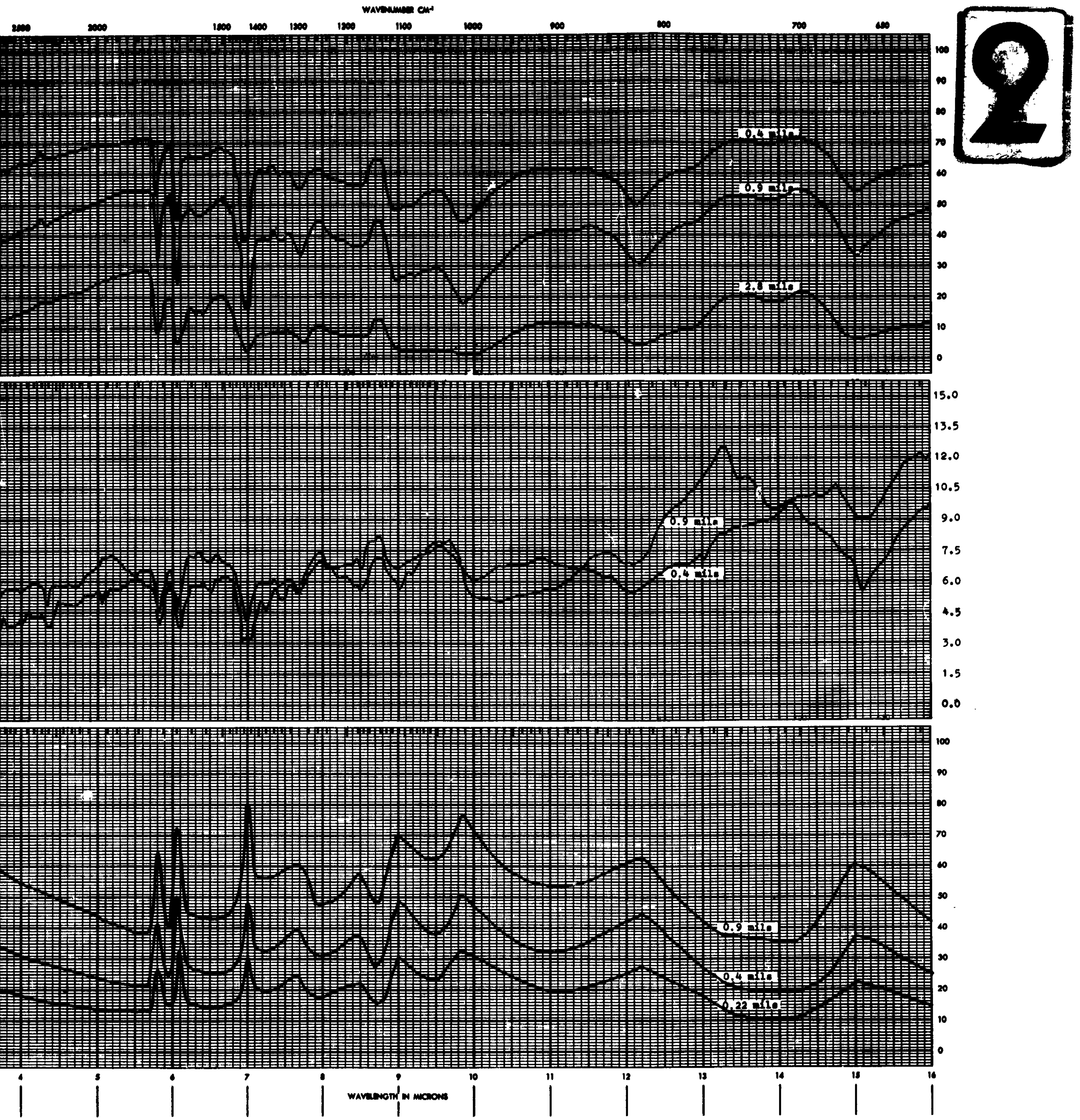


FIGURE 25

SPECTRAL TRANSMITTANCE, REFLECTANCE, AND ABSORPTIVITY IN PERCENT FOR BLACK NEOPRENE FILMS OF VARIOUS THICKNESSES


SPECTRAL TRANSMITTANCE, REFLECTANCE, AND ABSORPTIVITY IN PERCENT FOR BLACK NEOPRENE FILMS OF VARIOUS THICKNESSES
WAVENUMBER CM⁻¹
TRANSMITTANCE (%)
0.4 mils
0.9 mils
2.8 mils
REFLECTANCE (%)
0.9 mils
0.4 mils
ABSORPTIVITY (%)
0.9 mils
0.4 mils
0.22 mils
WAVELENGTH IN MICRONS
1

SPECTRAL TRANSMITTANCE, REFLECTANCE, AND ABSORPTIVITY IN PERCENT FOR BLACK NEOPRENE FILMS OF VARIOUS THICKNESSES



Whereas Figure 23 (top and center) are copies of the spectrometer charts, the curves on Figure 23 (bottom) are smoothed to indicate the important features only.

In addition to the absorptivity curves for the samples of 1.4, 0.83 and 0.5 mils thick, computations using these values of absorptivity were made to test the applicability of Beers' Law. It was found that the absorptivity as a function of thickness did indeed satisfy the condition to within experimental errors. On the basis of this, another absorptivity curve for a thickness of 0.22 mils was computed and drawn. This curve is also shown on Figure 23 (bottom).

The value 0.22 mils was used to approximate the thickness of a balloon four times its initial radius. This corresponds to an elevation of about 80,000 to 90,000 feet. By way of comparison, this curve agrees essentially with Figure 10, Page 291, on the basis of which computations on the radiative equilibrium temperature of a balloon were made. Since the new curve agrees so well with the previous extrapolated curve, the computed temperatures still stand.

Figure 24 is a set of similar transmittance, reflectance, and absorptivity curves for neoprene balloon film colored red. In all essential features, the near infra-red characteristics of the red neoprene are the same as those for white neoprene discussed above.

Figure 25 is a similar set of transmittance, reflectance, and absorptivity curves for black neoprene film. These curves show the same basic absorption bands as the white and red neoprene. However, a striking difference is also apparent.

Over all, the transmissivity of the black neoprene is less than the white or red neoprene. Scattering is still important in this range of 2 to 5 microns. This is true even with the film 0.4 mils thick. The reflectivity is also markedly different from the red and white neoprene. No interference patterns are apparent and the average reflectivity of the 0.4 and 0.9 mil black neoprene is higher than the white or red.

When the transmittance and reflectance values are added to deduce the absorptivity, it is found that the absorptivity of the black neoprene is consistently greater than that for the white and red neoprene films over the whole range 2 to 16 microns. This is particularly true in the region 2 to 6 microns and 7 to 14 microns.

FACTUAL DATA (continued)

TASK B, Phase 3 (continued)

The absorptivity of the black neoprene is about 1.5 times the absorptivity of the white or red neoprene in the region 9 to 11 microns. This is of particular importance since it is in this region that the terrestrial radiation is a maximum.

Spectrophotometers capable of making measurements of transmittance in the spectral range 16 to 40 microns have recently become available. It will now be possible to measure the spectral transmittance of the neoprene film in this region which encompasses about one-half the terrestrial radiation. These measurements on films of various thicknesses together with corresponding measurements in the ultra-violet, visible, and near infra-red of the total transmittance and reflectance will permit a more accurate determination of the radiative equilibrium temperatures.

Effect of Infra-Red Radiation on Physical Properties of Films

A preliminary study of the high-altitude flight results indicated that 2500-gram balloons made from compound A3-101 generally appeared to reach higher altitudes with greater consistency than did 2500-gram balloons made from A3-105. (Additional flights did not confirm this original conclusion.) It was, therefore, decided to determine whether these two compounds showed different behavior when exposed to infra-red radiation. At the same time, two additional compounds were made. These were derived by adding 10 parts of carbon black to compounds A3-101 and A3-105. These formulations are listed in Table 179.

Plates were dipped from these four compounds and cured for 60, 90, and 120 minutes at 260°F, 270°F, and 280°F. Physical properties were determined at room temperature in order to select an optimum cure at which to conduct the infra-red absorption study. The results of these tests are given in Table 180.

A study of these results shows that the compounds are all very flat curing. Addition of carbon black results in a marked increase in modulus and tensile strength with relatively little loss in elongation. The optimum cure for B3-1 was 90 minutes at 260°F, 60 minutes at 270°F for B3-2, 120 minutes at 260°F for B-3 and 120 minutes at 280°F for B3-4.

The excellent physical properties of compound B3-3 suggested that this compound should produce very good balloons. Accordingly, flights were performed and the results, which were extremely poor, are given in Task B, Phase 5.

In view of the very poor performance of the high absorption compounds, it was decided to abandon this line of research and to evaluate the possibilities of incorporating materials designed to reduce absorption of infra-red radiation. A series of compounds was designed, and their formulations are given in Table 181.

TABLE 179

FORMULATIONS WITH AND WITHOUT AN INFRA-RED ABSORBER

Formulation No.	B3-1	B3-2	B3-3	B3-4
Neoprene 750	80.0	100.0	80.0	100.0
Neoprene 571	20.0	-	20.0	-
Zinc Oxide	5.0	5.0	5.0	5.0
Neozone 'D'	2.0	2.0	2.0	2.0
N.B.C.	3.0	3.0	3.0	3.0
Accelerator 833	1.0	1.0	1.0	1.0
Sunaptic Acid	1.0	1.0	1.0	1.0
Aquarex SMO	0.5	0.5	0.5	0.5
Dibutyl Sebacate	6.25	10.0	6.25	10.0
Carbon Black	-	-	10.0	10.0

TABLE 180

PHYSICAL PROPERTIES OF COMPOUND B3-1, B3-2, B3-3, AND B3-4 TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
B3-1	60	260	125	175	280	2005	960	68
	90	260	130	175	295	2165	935	73
	120	260	130	190	295	1920	890	71
	60	270	130	175	285	2105	935	64
	90	270	130	180	295	2145	925	70
	120	270	135	175	305	2035	905	69
	60	280	130	175	280	2025	925	75
	90	280	130	170	280	2020	910	70
	120	280	135	185	295	2130	905	78
B3-2	60	260	85	105	170	1645	1265	50
	90	260	95	115	160	1600	1190	55
	120	260	115	155	200	1970	985	57
	60	270	110	140	195	2035	1015	58
	90	270	105	140	190	2020	995	60
	120	270	110	140	190	1985	1005	60
	60	280	80	110	170	2040	1015	56
	90	280	85	105	180	1805	985	62
	120	280	90	110	180	1940	975	60
B3-3	60	260	170	300	630	2425	990	139
	90	260	190	330	710	2855	945	146
	120	260	205	390	860	3360	925	142
	60	270	170	295	605	2445	1000	124
	90	270	190	330	705	2770	940	140
	120	270	195	350	750	3010	935	143
	60	280	180	310	650	2780	980	128
	90	280	185	340	750	2875	925	133
	120	280	205	370	815	2810	900	146
B3-4	60	260	130	235	500	2280	1160	109
	90	260	145	230	475	2535	1115	124
	120	260	145	230	480	2635	1110	132
	60	270	130	225	500	2325	1115	120
	90	270	140	225	475	2370	1105	110
	120	270	155	240	505	2950	1095	121
	60	280	130	230	475	2375	1115	109
	90	280	155	245	510	2905	1095	144
	120	280	165	305	650	3155	1005	145

FACTUAL DATA (continued)

TASK B, Phase 3 (continued)

TABLE 181

FORMULATIONS OF COMPOUNDS CONTAINING INFRA-RED REFLECTIVE INGREDIENTS

Formulation No.	B3-5	B3-6	B3-7	B3-8	B3-9	B3-10	B3-11	B3-12	B3-13
Neoprene 750	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Zinc Oxide	1.0	1.0	1.0	3.0	6.0	11.0	1.0	1.0	1.0
Titanium Dioxide	2.0	5.0	10.0	-	-	-	-	-	-
Lithopone	-	-	-	-	-	-	2.0	5.0	10.0
Neozone 'D'	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
N.B.C.	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Accelerator 833	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Sunaptic Acid	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Aquarex SMO	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Butyl Oleate	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0

FACTUAL DATA (continued)

TASK B, Phase 3 (continued)

Plates were dipped from these compounds according to standard procedure, cured for 60 minutes at 240°F and 60 minutes at 260°F and tested at room-temperature and at -40°C, -50°C and -60°C in the presence of and without infra-red radiation. The results of these tests are given in Tables 182 through 190.

A study of these results indicates that there is relatively little absorption of infra-red radiation as evidenced by change in physical characteristics. If these values are compared with those obtained with a compound containing carbon black, the difference in behavior is most marked.

Of the nine compounds tested, the ones containing Lithopone (B3-8, B3-9 and B3-10) show the greatest change on irradiation. Those containing Titanium Dioxise (Bs-5, B3-6 and B3-7) show the least change in modulus. The most interesting results, however, are shown by the compounds containing Zinc Oxide (B3-11, B3-12 and B3-13). Although these show slightly greater loss in modulus than do the Titanium Dioxide compounds, the tensile strength at low temperatures is practically unchanged on irradiation. At room-temperature, compound B3-13 shows a smaller loss in tensile strength than any other in the series. The maintenance of uniform tensile strength throughout a balloon is of utmost importance in ensuring that the whole balloon is capable of reaching its potential elongation.

The uneven conditions induced in a black balloon by solar radiation during flight resulted in a loss in altitude of almost 30,000 feet. That this was the reason was confirmed by the fact that post-plasticized black balloons, which still performed badly in the daytime, reached the anticipated normal bursting altitudes at night.

White balloons with a high zinc oxide content should, therefore, perform consistently in the daytime.

Accordingly, sufficient of this compound was made to dip balloons. Balloons in the 800-gram class were prepared. The physical properties of the compound were determined at room temperature and at -50°C, and the results are given in Table 191.

A study of these results suggests that the inherent characteristics of the compound should result in very good day-flight balloons. If the low infra-red radiation absorption proves to be a further asset, as theoretically as it should, then this compound should yield balloons having consistently high performance. It must, however, be borne in mind that since the absorption of infra-red radiation is reduced, the temperature of the balloon film will be lower than that of a similar balloon with higher infra-red absorption. It is possible, therefore, that additional plasticizer may have to be incorporated in the low infra-red absorption compounds in order to provide sufficient freeze resistance.

TABLE 182

EFFECT OF INFRA-RED RADIATION ON PHYSICAL PROPERTIES OF COMPOUND B-5

Test Temp. (°C)	Cure Time (mins)	Cure Temp. (°F)	Infra-Red Radiation	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
+20	60	240	no	100	125	255	1095	1020
-40	60	240	no	160	255	990	2500	730
-50	60	240	no	580	1260	-	3785	600
-60	60	240	no	-	-	-	3000	0
+20	60	240	yes	115	145	220	475	830
-40	60	240	yes	160	240	835	2305	770
-50	60	240	yes	315	540	2165	2300	610
-60	60	240	yes	1190	2055	-	2845	500
+20	60	260	no	115	155	240	940	980
-40	60	260	no	165	265	1165	2885	750
-50	60	260	no	1080	1970	-	4375	580
-60	60	260	no	-	-	-	3065	0
+20	60	260	yes	125	160	220	510	870
-40	60	260	yes	160	205	650	2090	790
-50	60	260	yes	285	385	1705	2580	690
-60	60	260	yes	875	1670	-	3780	560

TABLE 183

EFFECT OF INFRA-RED RADIATION ON PHYSICAL PROPERTIES OF COMPOUND B3-6

Test Temp. (°C)	Cure Time (mins)	Cure Temp. (°F)	Infra-Red Radiation	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
+20	60	240	no	110	150	280	865	970
-40	60	240	no	200	285	1265	3170	740
-50	60	240	no	845	1545	-	4465	580
-60	60	240	no	-	-	-	3000	0
+20	60	240	yes	135	175	235	500	840
-40	60	240	yes	170	255	995	2505	790
-50	60	240	yes	285	415	2095	2555	640
-60	60	240	yes	1120	1980	-	3490	540
+20	60	260	no	120	165	215	1115	1070
-40	60	260	no	180	305	1470	3780	730
-50	60	260	no	925	1695	4505	5275	630
-60	60	260	no	-	-	-	3260	0
+20	60	260	yes	145	165	230	670	910
-40	60	260	yes	180	240	705	2220	800
-50	60	260	yes	260	360	1835	3035	730
-60	60	260	yes	1300	1935	-	4485	610

TABLE 184

EFFECT OF INFRA-RED RADIATION ON PHYSICAL PROPERTIES OF COMPOUND B3-7

Test Temp. (°C)	Cure Time (mins)	Cure Temp. (°F)	Infra-Red Radiation	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
+20	60	240	no	115	160	280	1195	1010
-40	60	240	no	170	325	1330	3280	760
-50	60	240	no	1005	1725	-	5120	610
-60	60	240	no	-	-	-	3095	0
+20	60	240	yes	130	180	245	520	860
-40	60	240	yes	195	325	1170	2635	740
-50	60	240	yes	440	785	2060	2500	620
-60	60	240	yes	1080	1875	-	3410	560
+20	60	260	no	130	175	235	1220	1070
-40	60	260	no	185	325	1545	3400	740
-50	60	260	no	1185	1890	4485	5385	630
-60	60	260	no	-	-	-	3205	80
+20	60	260	yes	160	185	230	760	950
-40	60	260	yes	170	255	710	2415	830
-50	60	260	yes	305	450	1820	2990	700
-60	60	260	yes	1495	1980	-	4220	580*

* Cold flow

TABLE 185

EFFECT OF INFRA-RED RADIATION ON PHYSICAL PROPERTIES OF COMPOUND B3-8

Test Temp. (°C)	Cure Time (mins)	Cure Temp. (°F)	Infra-Red Radiation	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
+20	60	240	no	120	165	270	1205	890
-40	60	240	no	160	250	1610	3020	690
-50	60	240	no	905	2110	5390	5695	620
-60	60	240	no	-	-	-	3120	30
+20	60	240	yes	140	180	245	400	770
-40	60	240	yes	180	220	875	2380	750
-50	60	240	yes	230	300	1975	3425	690
-60	60	240	yes	1325	2295	5435	5435	600*
+20	60	260	no	140	170	250	1210	910
-40	60	260	no	175	315	1995	3195	680
-50	60	260	no	825	2195	4940	5945	640
-60	60	260	no	-	-	-	3665	0
+20	60	260	yes	140	175	240	315	690
-40	60	260	yes	160	210	930	3530	790
-50	60	260	yes	245	375	2035	3250	710
-60	60	260	yes	1610	2550	-	5205	590*

* Cold flow

TABLE 186

EFFECT OF INFRA-RED RADIATION ON PHYSICAL PROPERTIES OF COMPOUND B3-9

Test Temp. (°C)	Cure Time (mins)	Cure Temp. (°F)	Infra-Red Radiation	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
+20	60	240	no	110	150	250	990	930
-40	60	240	no	150	240	1520	3510	730
-50	60	240	no	865	1725	5090	5300	610
-60	60	240	no	-	-	-	3335	0
+20	60	240	yes	145	190	255	440	780
-40	60	240	yes	165	225	920	2545	780
-50	60	240	yes	210	315	1795	3150	680
-60	60	240	yes	1500	2400	-	4550	580*
+20	60	260	no	150	180	270	1430	910
-40	60	260	no	170	260	1780	3910	700
-50	60	260	no	810	2055	5410	6110	620
-60	60	260	no	-	-	-	3075	0
+20	60	260	yes	135	185	230	350	730
-40	60	260	yes	165	220	945	2860	730
-50	60	260	yes	245	340	2010	4785	700
-60	60	260	yes	1000	1865	-	450	590*

* Cold flow

TABLE 187

EFFECT OF INFRA-RED RADIATION ON PHYSICAL PROPERTIES OF COMPOUND B3-10

Test Temp. (°C)	Cure Time (mins)	Cure Temp. (°F)	Infra-Red Radiation	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
+20	60	240	no	120	165	270	1085	930
-40	60	240	no	175	315	1770	3775	720
-50	60	240	no	610	1680	4605	5485	640
-60	60	240	no	-	-	-	2915	0
+20	60	240	yes	160	190	255	475	790
-40	60	240	yes	155	260	860	2865	790
-50	60	240	yes	235	370	1810	3805	710
-60	60	240	yes	1535	2450	-	4425	570*
+20	60	260	no	145	175	255	1315	930
-40	60	260	no	170	410	2060	4405	720
-50	60	260	no	905	2080	-	5738	610
-60	60	260	no	-	-	-	3655	0
+20	60	260	yes	140	175	240	390	760
-40	60	260	yes	180	260	1105	3460	760
-50	60	260	yes	260	400	2085	4050	680
-60	60	260	yes	1090	1890	4550	5105	620*

* Cold flow

TABLE 188

EFFECT OF INFRA-RED RADIATION ON PHYSICAL PROPERTIES OF COMPOUND B3-11

Test Temp. (°C)	Cure Time (mins)	Cure Temp. (°F)	Infra-Red Radiation	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
+20	60	240	no	130	145	255	1025	980
-40	60	240	no	150	230	1305	3045	740
-50	60	240	no	510	1465	3565	4135	630
-60	60	240	no	-	-	-	3250	60*
+20	60	240	yes	135	170	240	525	910
-40	60	240	yes	165	225	740	3010	820
-50	60	240	yes	225	355	1705	3405	720
-60	60	240	yes	1300	2170	-	4235	580*
+20	60	260	no	130	165	220	1235	960
-40	60	260	no	185	265	1880	3510	680
-50	60	260	no	1145	1915	-	4450	590
-60	60	260	no	-	-	-	3370	0
+20	60	260	yes	130	165	215	545	810
-40	60	260	yes	180	210	810	3345	820
-50	60	260	yes	265	400	2300	3800	660
-60	60	260	yes	770	1545	3935	4335	620*

* Cold flow

TABLE 189

EFFECT OF INFRA-RED RADIATION ON PHYSICAL PROPERTIES OF COMPOUND B3-12

Test Temp. (°C)	Cure Time (mins)	Cure Temp. (°F)	Infra-Red Radiation	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
+20	60	240	no	110	135	245	1060	1060
-40	60	240	no	165	280	1445	3195	720
-50	60	240	no	935	1835	4765	4900	610
-60	60	240	no	-	-	-	3250	0
+20	60	240	yes	135	170	240	615	950
-40	60	240	yes	160	230	815	2755	780
-50	60	240	yes	315	410	2635	3795	690
-60	60	240	yes	1385	2340	-	3270	550*
+20	60	260	no	135	160	220	1210	960
-40	60	260	no	165	300	2110	4000	710
-50	60	260	no	1215	2095	4490	4660	610
-60	60	260	no	-	-	-	3685	0
+20	60	260	yes	130	165	215	600	930
-40	60	260	yes	180	245	865	3240	800
-50	60	260	yes	310	480	2360	4660	700
-60	60	260	yes	1175	1705	5000	5000	600*

* Cold flow

TABLE 190

EFFECT OF INFRA-RED RADIATION ON PHYSICAL PROPERTIES OF COMPOUND B3-13

Test Temp. (°C)	Cure Time (mins)	Cure Temp. (°F)	Infra-Red Radiation	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
+20	60	240	no	125	155	270	960	1040
-40	60	240	no	205	375	1645	2705	690
-50	60	240	no	980	1825	-	4665	590
-60	60	240	no	-	-	-	3145	0
+20	60	240	yes	135	175	240	620	980
-40	60	240	yes	170	285	880	2640	780
-50	60	240	yes	275	545	2125	3450	680
-60	60	240	yes	845	1115	-	3555	590*
+20	60	260	no	135	180	240	1175	1030
-40	60	260	no	205	345	1890	3075	700
-50	60	260	no	1005	2400	4725	5665	640
-60	60	260	no	-	-	-	4145	0
+20	60	260	yes	155	200	250	795	970
-40	60	260	yes	190	280	1030	3065	770
-50	60	260	yes	325	650	2530	3965	700
-60	60	260	yes	1105	1715	-	4010	570*

* Cold flow

FACTUAL DATA (continued)

TASK B, Phase 3 (continued)

TABLE 191

PHYSICAL PROPERTIES OF COMPOUND B3-13 DETERMINED AT ROOM TEMPERATURE AND AT -50°C.

Test Temp. (C.)	Cure Time (mins)	Cure Temp. (F.)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Tear Strength (lbs/in)
+20	60	260	115	155	255	2035	1110	75
+20	90	260	125	180	290	2185	1035	78
+20	120	260	135	185	295	2270	980	75
+20	60	280	115	165	265	2035	1000	70
+20	90	280	135	195	315	2425	970	78
+20	120	280	150	225	440	2695	930	92
-50	60	260	740	1640	4570	4570	600	--
-50	90	260	1000	2250	5675	5835	610	--
-50	120	260	1210	2380	5765	5765	600	--
-50	60	280	1205	2415	5595	5950	610	--
-50	90	280	1250	2785	6048	6470	610	--
-50	120	280	1759	3380	6205	6205	600	--

FACTUAL DATA (continued)

TASK B (continued)

Phase 4: Effect of Ultra-Violet and Other Short-Wave Radiation

Exploratory experiments were conducted using a Hanovia ultra-violet lamp with maximum radiation concentration at 3600 A°. A six-inch, tubular lamp was used; and three compounds were selected for evaluation. These were A3-105 which contains 3 parts of N.B.C., A3-117 which contains 3 parts of Agerite DPPD, and a compound identified as B4-1 which is identical to A3-105, but from which the N.B.C. was eliminated and no other antiozonant included.

Dumbbell samples were cut from each of the films made from these compounds and stretched to an elongation of 300%. The atmosphere in the testing chamber was replaced by nitrogen to avoid any side effects produced by ozone, although the wave-length of 3600A° produces little, if any, ozone.

The samples were exposed for periods of one hour and two hours, and then removed from the test chamber, allowed to relax for one hour, and tested on the Scott Tester. The physical characteristics of these films before and after exposure to the ultra-violet lamp are given in Table 192.

In order to eliminate the effect of stretching the samples to 300% before testing, controls which had been stretched to this elongation for the same length of time but not exposed to ultra-violet radiation were also tested.

A study of these results shows that in the wavelength range tested, ultra-violet radiation has no effect on the physical properties of the compounds under investigation. A few spot checks were made with air instead of nitrogen in the chamber, and again no variation in physical properties could be determined after irradiation with ultra-violet light.

Four General Electric #G-4-S11 bulbs which have maximum radiation at 2800 A° were now obtained, this wave-length being much more active than 3600A°. The four bulbs were mounted in a plane, and the dumbbell samples under test were supported at a distance of approximately six inches from the plane of the bulbs. The dumbbells were stretched to an elongation of 300% and exposed for periods of two hours and four hours. One series of tests was conducted in an atmosphere of nitrogen and another in an atmosphere of air.

Three compounds were again used in this investigation: (1) A3-105, a day-flight compound, (2) A3-105 post-plasticized for night flight, (3) A3-104, a dual purpose compound. Physical properties of the compounds were determined before and after exposure to ultra-violet radiation. The results of these tests are given in Table 193.

FACTUAL DATA (CONTINUED)

TASK B PHASE 4 (CONTINUED)

TABLE 192

PHYSICAL CHARACTERISTICS OF BALLOON FILMS BEFORE AND AFTER EXPOSURE TO ULTRA-VIOLET RADIATION - TESTED AT ROOM TEMPERATURE

Compound No.	Cure Time (mins)	Cure Temp. (°F)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)	Treatment
A3-105	60	280	120	165	215	1800	940	None
	60	280	120	160	220	1820	950	No UV exp*
	60	280	115	165	215	1850	940	1 hr UV exp*
	60	280	120	165	210	1860	940	2 hr UV exp*
	90	280	120	170	240	1905	950	None
	90	280	120	165	240	1900	945	No UV exp*
	90	280	120	170	230	1900	950	1 hr UV exp*
	90	280	120	165	235	1920	945	2 hr UV exp*
	120	280	115	160	240	2185	960	None
	120	280	120	165	230	2160	955	No UV exp*
	120	280	120	155	245	2175	970	1 hr UV exp*
	120	280	120	155	240	2170	965	2 hr UV exp*
B4-1	60	280	110	145	175	1660	1020	None
	60	280	110	140	175	1670	1015	No UV exp*
	60	280	100	135	170	1680	1000	1 hr UV exp*
	60	280	110	140	165	1700	1010	2 hr UV exp*
	90	280	115	165	210	1990	1010	None
	90	280	120	160	210	1940	1000	No UV exp*
	90	280	115	150	200	1880	1020	1 hr UV exp*
	90	280	115	165	200	1895	1005	2 hr UV exp*
	120	280	115	155	205	1920	970	None
	120	280	110	160	210	1900	960	No UV exp*
	120	280	110	150	195	1850	970	1 hr UV exp*
	120	280	115	155	200	1880	965	2 hr UV exp*
A3-117	60	280	135	200	390	1580	870	None
	60	280	140	190	385	1610	880	No UV exp*
	60	280	140	210	370	1595	850	1 hr UV exp*
	60	280	130	185	375	1630	845	2 hr UV exp*
	90	280	155	215	430	1600	840	None
	90	280	150	220	410	1640	870	No UV exp*
	90	280	150	205	425	1655	790	1 hr UV exp*
	90	280	150	220	405	1640	820	2 hr UV exp*
	120	280	160	225	440	1710	810	None
	120	280	160	230	435	1680	800	No UV exp*
	120	280	155	240	410	1670	820	1 hr UV exp*
	120	280	165	240	430	1690	820	2 hr UV exp*

* Samples stretched to an elongation of 300%.

FACTUAL DATA (continued)

TABLE 193

EFFECT OF ULTRA-VIOLET RADIATION ON BALLOON FILMS TESTED AT ROOM-TEMPERATURE

Compound No.	Atmosphere	Time of Exposure (hours)	Modulus at 200% (psi)	Modulus at 400% (psi)	Modulus at 600% (psi)	Tensile Strength (psi)	Elongation at Break (%)
A3-105	Air	0	130	210	395	2275	890
	Air	2	135	180	340	2480	935
	Air	4	samples broke due to ozone attack				
	Nitrogen	0	130	210	395	2275	890
	Nitrogen	2	115	205	345	2135	915
	Nitrogen	4	145	210	350	2015	890
A3-105 post-plasti-cized	Air	0	105	170	320	1375	820
	Air	2	samples broke due to ozone attack				
	Nitrogen	0	105	170	320	1375	820
	Nitrogen	2	85	130	240	1330	850
	Nitrogen	4	60	115	215	1060	830
A3-104	Air	0	125	280	610	1830	905
	Air	2	samples broke due to ozone attack				
	Nitrogen	0	125	280	610	1830	905
	Nitrogen	2	105	245	540	1725	925
	Nitrogen	4	100	240	540	1700	925

FACTUAL DATA (continued)

TASK B, Phase 4 (continued)

A study of this table shows that the intensity of the ultra-violet radiation was sufficient to create substantial concentrations of ozone in an atmosphere of air.

After two hours, compound A3-105 showed a slight drop in modulus and a slight increase in tensile strength and elongation. After four hours, the samples showed too much ozone attack, making it impossible to obtain physical properties.

In the case of the post-plasticized dumbbells and those cut from dual-purpose compound film, the deterioration due to ozone attack was too great after two hours exposure to enable the determination of physical properties.

The dumbbells cut from A3-105 when exposed in a nitrogen atmosphere showed virtually no change in any physical characteristics other than an almost insignificant drop in modulus at 600% elongation.

However, the same compound after post-plasticizing showed a steady fall in modulus and tensile strength as the time of exposure increased. There was no significant change in elongation.

The dual-purpose compound showed a significant loss in modulus at all elongations after two hours exposure and a much smaller loss in tensile strength. After a further two hours there was no further change in modulus or tensile strength. This was accompanied by a slight increase in elongation during the first two hours, and no further change between two and four hours exposure.

It would seem, therefore, that the major deterioration which a balloon is likely to suffer upon exposure to ultra-violet radiation during a flight is attributable to attack by ozone which the ultra-violet radiation has created. Since a comprehensive study of the action of ozone on balloon films had already been conducted, there seems to be no advantage to extending this study of the effect of ultra-violet radiation any further.

FACTUAL DATA (continued)

TASK B (continued)

Phase 5: Correlation of Physical Properties with Flight Performance

The excellent physical properties of compound B3-3 coupled with the knowledge that such a compound absorbs strongly in the infra-red suggest that balloons should show good day-time performance. Accordingly, 800-gram balloons were manufactured from this compound and submitted for flight testing. In order to determine the influence of the carbon black, a balloon of similar weight manufactured from compound B3-1 which is identical with B3-3 apart from the carbon black was used as a control with each black balloon flight.

All balloons were flown during the hours of daylight with a free lift of 1600 grams. The control balloons are identified as EX-3B-101 through EX-3B-106, and the black balloons as EX-3B-111 through EX-3B-116. The characteristics of these balloons and their flight performance are recorded in Table 194. Each control and experimental flight are paired for ease of reference.

A study of these results shows with startling clarity that the addition of carbon black has resulted in a loss of altitude of about 30,000 feet. The physical properties of the black compound, coupled with the greater length of the black balloons, would normally, however, lead to an expectation of much improved performance.

The previous evaluation of a black compound during Contract DA-36-039-SC-78239 showed that absorption of infra-red radiation results in a marked loss of tensile strength and modulus as well as an increase in low-temperature elongation. The possibility that this might lead to large differences in these properties within a balloon was anticipated in the final report of Contract DA-36-039-SC-78239.

The flight results obtained indicates that this is the case. The upper portion of the balloon apparently absorbs radiation to such an extent that its tensile strength and modulus are very substantially reduced.

The effect is magnified since little, if any, solar radiation now reaches the lower part of the balloon which is in the shadow of the upper part. It is, in fact, possible that so little radiation is reaching the lower part of the balloon that it is freezing.

In order to confirm this theory, balloons of the same type were post-plasticized to render them suitable for night flight. If the solar radiation theory is correct, these balloons should fly satisfactorily at night. Prevention of the lower half of the balloon from freezing should possibly improve the day-flight performance, but variations in absorption of solar radiation throughout the film may still result in inferior flights to those obtained with uncolored balloons.

FACTUAL DATA (continued)

TABLE 194

FLIGHT RESULTS - BALLOONS MADE FROM COMPOUND CONTAINING CARBON BLACK

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Flaccid Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3B-101	K241	Day	795	91	102,700	1078
EX-3B-114	K20-3	Day	820	107	67,600	1110
EX-3B-102	K242	Day	815	96	110,300	1167
EX-3B-113	K17-8	Day	855	118	80,900	1093
EX-3B-103	K243	Day	800	93	104,200	1079
EX-3B-112	K17-7	Day	835	112	73,900	1051
EX-3B-104	K244	Day	800	90	100,000	1177
EX-3B-116	K20-6	Day	860	107	63,000	1073
EX-3B-105	K245	Day	850	96	75,100	1081
EX-3B-111	K17-6	Day	840	118	71,000	1087
EX-3B-106	K246	Day	810	94	103,000	1133
EX-3B-115	K20-5	Day	855	108	66,500	1118

TABLE 195

FLIGHT RESULTS - BALLOONS MADE FROM COMPOUND CONTAINING CARBON BLACK

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Flaccid Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3B-201	K21-4	Day	1045	117	82,300	986
EX-3B-202	K21-3	Night	1015	118	90,500	1035
EX-3B-203	K21-5	Night	1030	118	115,060	1092
EX-3B-204	K21-6	Night	1050	119	112,000	1031

FACTUAL DATA (continued)

TASK B (continued)

Four such balloons were submitted for flight testing. One of these was flown during the hours of daylight and the remaining three at night. All balloons were flown with a free lift of 1600 grams. The characteristics of these balloons and their flight performance are given in Table 195.

A study of these results shows that the average night-time performance is much superior to the day-time performance. Balloons EX-3B-203 and EX-3B-204 are superior to any of the day-flight balloons which did not contain carbon black. There seems little doubt, therefore, that balloon compounds which show high infra-red radiation absorption are unsatisfactory for daytime use.

Balloons were made from a compound containing Agerite DPPD which provides much better ozone resistance than does N.B.C. according to laboratory tests. This compound, designated A3-117, is described in Task A, Phase 3, Part A.

Six balloons were made from compound A3-105 which is similar to A3-117 except that it does not contain Agerite DPPD. These were identified as EX-2B-101 through EX-2B-106.

Six balloons were made from compound A3-117 which contains Agerite DPPD. These were identified as EX-2B-111 through EX-2B-116.

These twelve balloons were flown in pairs on the same day as follows:

EX-2B-101 and EX-2B-114	EX-2B-102 and EX-2B-116
EX-2B-103 and EX-2B-112	EX-2B-104 and EX-2B-115
EX-2B-105 and EX-2B-111	EX-2B-106 and EX-2B-114

All balloons were flown during the daytime with a free lift of 1600 grams. The characteristics of these balloons and their flight performance are given in Table 196.

An analysis of these results shows that the balloons made from compound A3-117 consistently reach altitudes approximately 10,000 feet lower than do the balloons made from compound A3-105. The only explanation that is immediately apparent is based on the color of the balloons.

Agerite DPPD produces a balloon which is substantially darker in color. It has already been shown that black balloons reach much lower altitudes in the daytime. Hence, the darker color of the balloons containing Agerite DPPD may be responsible for the reduced altitudes.

FACTUAL DATA (continued)

TABLE 196

FLIGHT RESULTS - BALLOONS MADE FROM COMPOUNDS A3-105 AND A3-117

Experiment No.	Balloon No.	Compound No.	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-2B-101	Y14-1P	A3-105	880	98	102,000	1043
EX-2B-102	Y14-2P	A3-105	870	100	104,000	1084
EX-2B-103	Y14-3P	A3-105	870	98	104,500	1107
EX-2B-104	Y14-4P	A3-105	865	98	102,200	1054
EX-2B-105	Y14-5P	A3-105	880	98	102,000	1036
EX-2B-106	Y14-6P	A3-105	820	102	101,000	1068
EX-2B-111	Y5-4KT	A3-117	910	102	92,300	1068
EX-2B-112	Y9-3KT	A3-117	880	99	96,200	1192
EX-2B-113	Y9-5KT	A3-117	880	101	81,910	1082
EX-2B-114	Y14-2KT	A3-117	880	98	93,200	1107
EX-2B-115	Y14-3KT	A3-117	910	100	91,700	1074
EX-2B-116	Y15-1KT	A3-117	870	100	89,000	1095

TABLE 197

FLIGHT RESULTS - BALLOONS MADE FROM COMPOUND B3-13

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3B-121	H8-2TN	Day	795	92	94,500	1099
EX-3B-122	H8-4TN	Day	845	94	90,700	1043
EX-3B-123	H9-5TN	Day	835	91	92,300	1034

FACTUAL DATA (continued)

TASK B, Phase 5 (continued)

Three balloons manufactured from compound B3-13 were submitted for flight testing. This compound shows extremely low infra-red absorption and, consequently, shows very little difference in physical characteristics whether or not the film is subjected to infra-red radiation.

It was felt, therefore, that the physical properties throughout a balloon during a daytime flight would be much more uniform than is the case where the film absorbs radiation with consequent reduction in tensile strength and modulus.

The three balloons were flown with a free lift of 1600 grams, and their flight performance is given in Table 197.

A study of this table shows that, although the altitudes reached are relatively consistent, the actual altitude is no greater than is normally obtained with this size balloon. In fact, better altitudes for balloons of this weight and length have been recorded using standard balloon compounds.

As pointed out in Task B, Phase 3, the reduced infra-red absorption of compound B3-13 may result in the balloon having a lower temperature during a daytime flight. If this is the case, the ultimate elongation of the balloon film will also be lower than that of a normal balloon, part of which at least is being raised to greater temperatures by solar radiation.

Increasing the plasticizer content of compound B3-13 should, therefore, improve the altitude obtainable by increasing the elongation of the film at the temperature which it attains during flight. At the same time, the uniformity of physical properties throughout the film should still be maintained with a consequent improvement in consistency of flight performance.

Phase 6: Prediction of Balloon Flight Performance

Part A: Determination of Burst Altitude from Residual Elongation

A system of nomograms for predicting balloon flight performance was developed. An elongation-temperature curve is derived for the compound, and by superimposing this curve over the nomogram for the proper balloon size, it is possible to determine at what height the residual elongation of the balloon becomes zero. This new means of prediction is superior to the flight equation and the slide rule methods developed during Contract DA-36-039-SC-72386 and is described in detail in the following pages.

DETERMINATION OF BALLOON RESIDUAL ELONGATION

In the day-to-day use of high altitude balloons, it would be useful to have a means to predict the expected performance of the balloons in terms of the known or expected atmospheric temperature conditions. A useful parameter in this connection is the Residual Elongation of the balloon. By this is meant the difference between the actual and ultimate elongation at any particular elevation. This can be expressed as:

$$E_r = E_u - E_a \qquad (1)$$

where:

E_r is the residual elongation.

E_u is the ultimate elongation and is a characteristic of the particular neoprene compound used in fabricating the balloon. E_u is, for our purposes, chiefly a function of the temperature of the neoprene.

E_a is the actual elongation.

Elongation is usually expressed in percent and is defined as follows:

$$E_a = \frac{r_a - r_o}{r_o} \times 100\% \qquad (2)$$

Here, r_a is the actual radius of the balloon, and

r_o is the flaccid or barely inflated radius.

Rather than solve the equations of balloon flight numerically or by means of many manipulations on a slide rule, both of which have been found to be inconvenient procedures, a nomogram has been developed relating the parameters of principal importance to permit a very convenient method of graphical solution. These nomograms, one for the 1000-gram, 100,000-foot balloon and one for the 1750-gram, 120,000-foot balloon, will be presented later.

Theory of Balloon Expansion

It has been observed that the density of the rubber or neoprene comprising the fabric of a balloon is very nearly conserved as the balloon expands. It can be shown as well to a sufficient degree of accuracy that the difference between the gas pressure inside an inflated balloon and the ambient air pressure is very small, even at the bursting pressure. In view of this, it is assumed that the pressure of the gas inside the balloon is the same as that of the atmospheric environment and that, therefore, the gas law as applied to the balloon is:

$$\frac{pv}{T} \propto \frac{pr^3}{T} = \text{const.} \qquad (3)$$

where:

p is the gas pressure inside the balloon and may be measured by the ambient air pressure.

v is the volume of the balloon at the elevation corresponding to pressure, p.

T is the temperature of the gas in the balloon and as a first approximation is assumed to be the same as the air temperature as well as the balloon fabric.

r is the radius of the balloon.

The assumption of inside and outside temperature equality will be discussed in a separate section later.

If subscript (o) refers to an initial or flaccid condition of the balloon and subscript (a) refers to the variable or final condition, the radius of a balloon may be determined by writing equation (3) in the following form:

$$3 \log r_a = 3 \log r_o + \log (p_o - p_a) + \log (T_a - T_o) \qquad (4)$$

The elongation at any elevation whose pressure (p_a) and temperature (T_a) are known can be determined from equations (4) and (2). By comparing E_a with the known ultimate elongation characteristic at the temperature (T_a), the residual elongation may be calculated.

Construction of the Nomogram

Figure 26 is a chart for the graphical solution of equations (4), (2), and (1). The diagram contains three principal features:

a. The elongation as a function of pressure alone

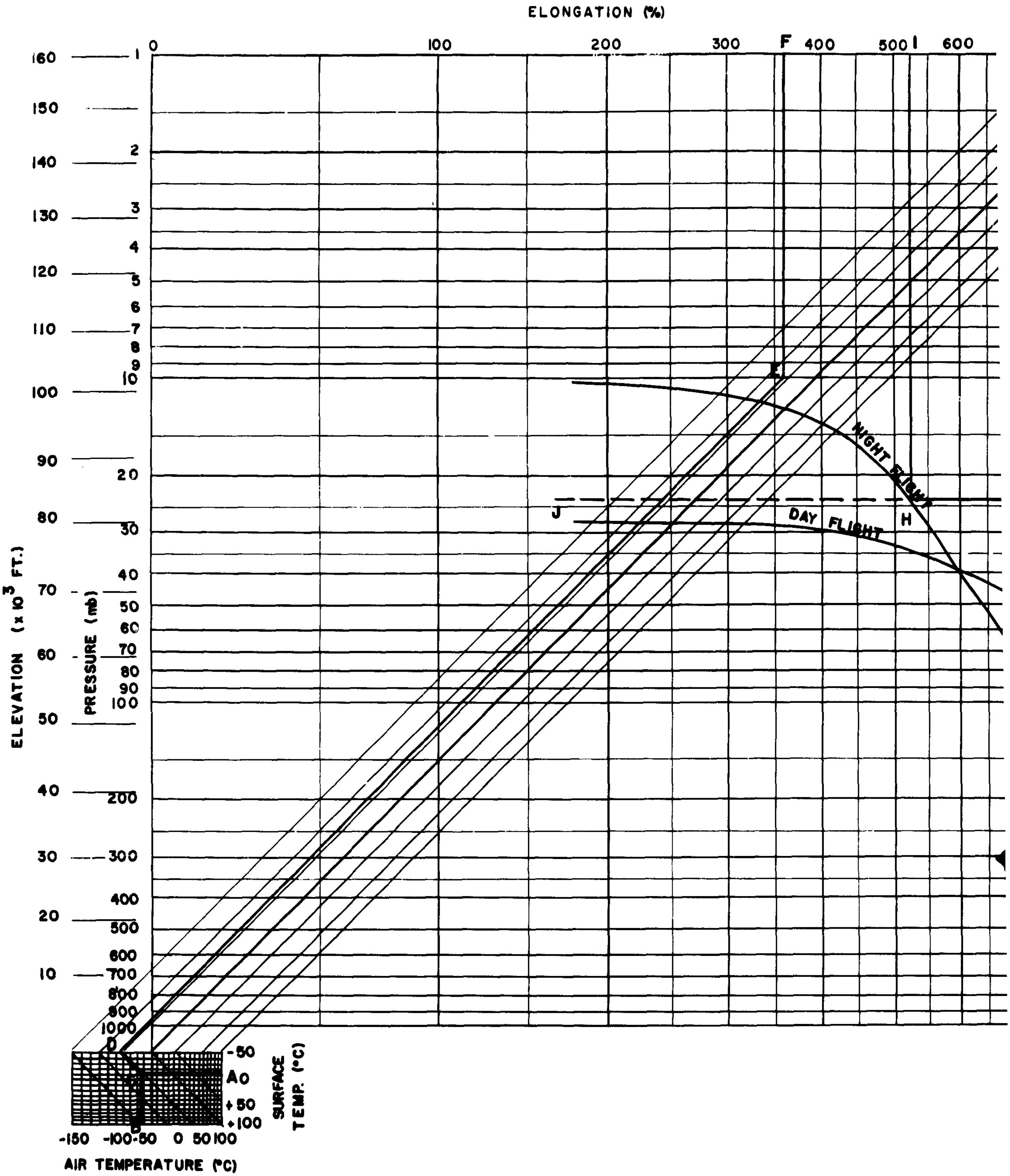
b. The effect of temperature on the elongation

c. A presentation of the empirical isothermal ultimate elongation characteristics of day-flight and night-flight neoprene compounds.

With regard to the main body of the nomogram, the ordinate is -log p, labeled on the left side of the chart. Note that pressure decreases upward as is conventional on most meteorological charts depicting atmospheric pressure related to elevation. The pressure ranges over three orders of magnitude. The abscissa is the radius plotted as log r but on a scale three times that of pressure and thus actually represents 3 log r. However, in view of equation (2), the scale is labeled in terms of elongation instead of radius across the top of the chart. The relationship between p and r (or elongation) on this (-log p, 3 log r) chart is a straight diagonal line whose slope is 45° and is drawn as a heavy sloping line on the diagram. The reference pressure (p_o) and radius (r_o) given by the intersection of the heavy sloping line with the zero elongation line represents the condition under which the balloon is just barely inflated. Any point along the heavy diagonal line thus represents the isothermal expansion of the balloon at temperature (T_o).

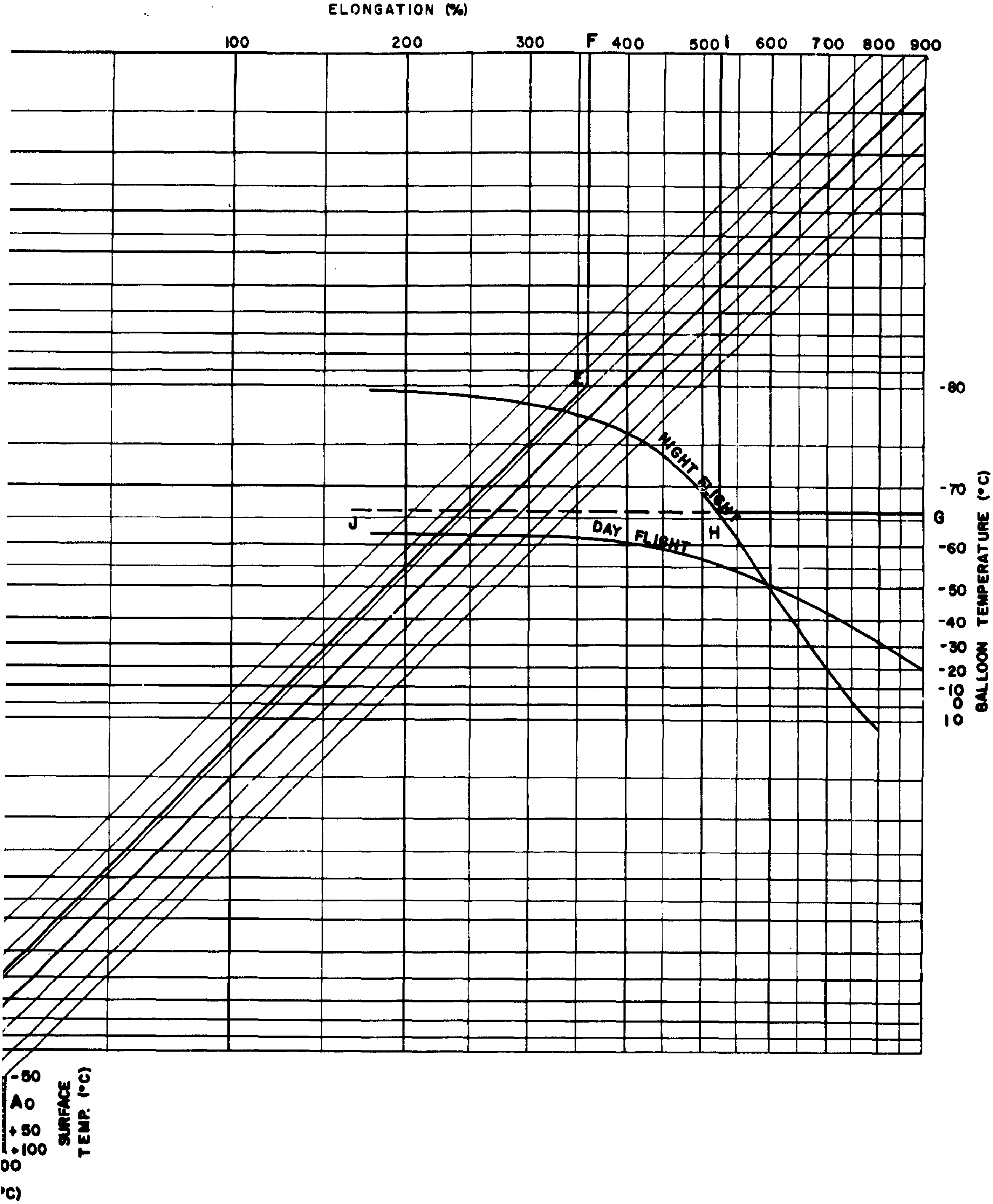
FIGURE 26

USE OF NOMOGRAM TO DETERMINE RESIDUAL ELONGATION FOR 1000-GRAM BALLOON



ELONGATION (%)
0
100
200
300
F
400
500
I
600
ELEVATION (x 10³ FT.)
PRESSURE (mb)
NIGHT FLIGHT
DAY FLIGHT
J
H
E
D
A
B
SURFACE TEMP. (°C)
AIR TEMPERATURE (°C)

1



ELONGATION (%)
100
200
300
F
400
500
I
600
700
800
900
E
NIGHT FLIGHT
DAY FLIGHT
J
H
G
-80
-70
-60
-50
-40
-30
-20
-10
0
10
BALLOON TEMPERATURE (°C)
-50
Ao
+50
+100
SURFACE TEMP. (°C)

To solve for 3 log r_a, log (T_a - T_o) must be added algebraically to 3 log r_o + log (p_o - p_a).

This is accomplished by means of the auxilliary graph at the lower left of the chart. Here, log T_o (usually the surface temperature) is the vertical scale and log T_a (the ambient air temperature) is the abscissa. These are actually plotted on the absolute temperature scale as is required in the gas law, but are labeled in degrees Celsius for convenience in use. The value of log (T_o - T_a) is determined by noting the locus of the point whose coordinates are the arguments. The addition is accomplished by proceeding diagonally upward to the left parallel to the diagonal straight lines to the reference level.

Finally, the isothermal ultimate elongation characteristics for the night-flight and day-flight neoprene compounds have been drawn as curved lines on the right side of the main chart. The scale used is temperature of the neoprene in degrees Celsius plotted on the right side of the chart versus ultimate elongation of the neoprene using the same horizontal scale at the top of the chart as before.

Procedure for Using the Nomogram

The procedure for using the chart to determine the residual elongation of a balloon at a particular elevation may best be illustrated by means of an example. Suppose a 1000-gram balloon flown at night is at an elevation corresponding to 10 mb. pressure where the temperature is 216°K or -67°C. Further, suppose the surface or launching temperature is -10°C and the surface pressure is 1000 mb. What is the residual elongation, if any, left in the balloon at that elevation?

Refer to Figure26 for the solution. The pressure versus elongation have been determined for the 1000-gram balloon whose flaccid diameter is 5.5 feet and whose diameter at release is 6.05 feet. The ratio of r_a to r_o is thus 1.1 or the initial elongation at launching is 10%. Note that the sloping heavy diagonal line passes through this point.

1. Note the surface temperature (-10°C) at point A and the free air temperature (-67°C) at point B. Find point C whose coordinates are these values.
2. Proceed upward to the left parallel to the sloping straight lines to D. The length from elongation zero to D represents log $(T_o - T_a)$.
3. From D, follow parallel to the sloping diagonal lines to the ambient pressure (10 mb.) at point E. This represents log $(p_a - p_o)$ plus log $(T_o - T_a)$.
4. The actual elongation may now be read at the top scale point F as 360%. The diameter of the balloon at this elevation is now 4.6 times its flaccid diameter.

The next step is to determine what the ultimate elongation of the balloon is corresponding to the temperature (-67°C).

5. Start at point G at -67°C on the right side scale of the chart and move horizontally to the left to point H on the ultimate elongation curve for the night-flight compound.
6. The ultimate elongation for this compound and temperature is read at I (520%).

7. The residual elongation is thus 520% - 360% equals 160%. Or the balloon is capable of expanding another 1.6 initial diameters.

If this had been a day flight instead of a night flight, and the temperature had been the same, step 5 would have proceeded to J instead of to H. It is clear from this that the balloon would have burst prior to reaching 10 mb. as the ultimate elongation of the neoprene would have been exceeded.

Figure 27 is a blank diagram for use with the 1000-gram balloon, and Figure 28 is for use with the 1750 gram balloon, the barely inflated diameter of which is 7.166 feet. This balloon is not completely inflated when launched, the volume of gas at launch being 135 feet^3. This means that under normal conditions, the balloon will not be barely inflated until it has risen to about 710 mb. Consequently, the heavy diagonal line in Figure 28 intersects the zero elongation line at about 710 mb.

Limitations and Approximations

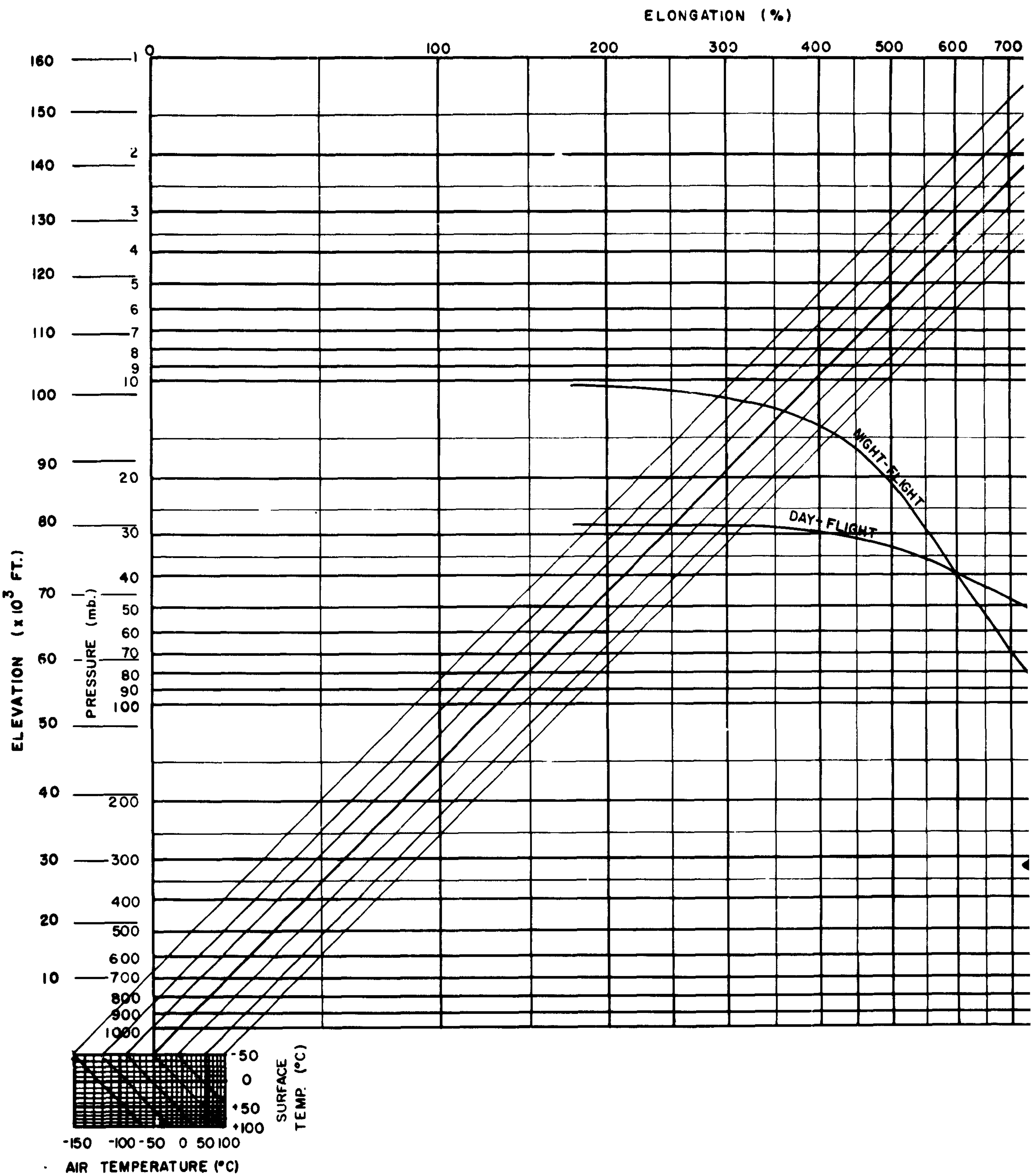
Some basic approximations have been made in developing these charts, and these, consequently, limit their validity. These will be discussed here.

1. The assumption that the air pressure may be substituted for the balloon gas pressure in the gas equation. Measurement of the modulus of the neoprene when used in the equation for the pressure difference indicates this difference to be very much smaller than the gas pressure.
2. The charts have been drawn to indicate the barely inflated pressure to be 1000 mb. and 710 mb., respectively. If these are in error by as much as 5% (an excessively large error), the effect upon the radius varies as the cube root or the elongation will be in error less than 2%.

FIGURE 27

NOMOGRAM FOR DETERMINATION OF RESIDUAL ELONGATION OF 1000-GRAM BALLOON

1


ELONGATION (%)
0
100
200
300
400
500
600
700
ELEVATION (x 10^3 FT.)
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
PRESSURE (mb.)
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000
NIGHT-FLIGHT
DAY-FLIGHT
-50
0
+50
+100
SURFACE TEMP. (°C)
-150
-100
-50
0
50
100
AIR TEMPERATURE (°C)

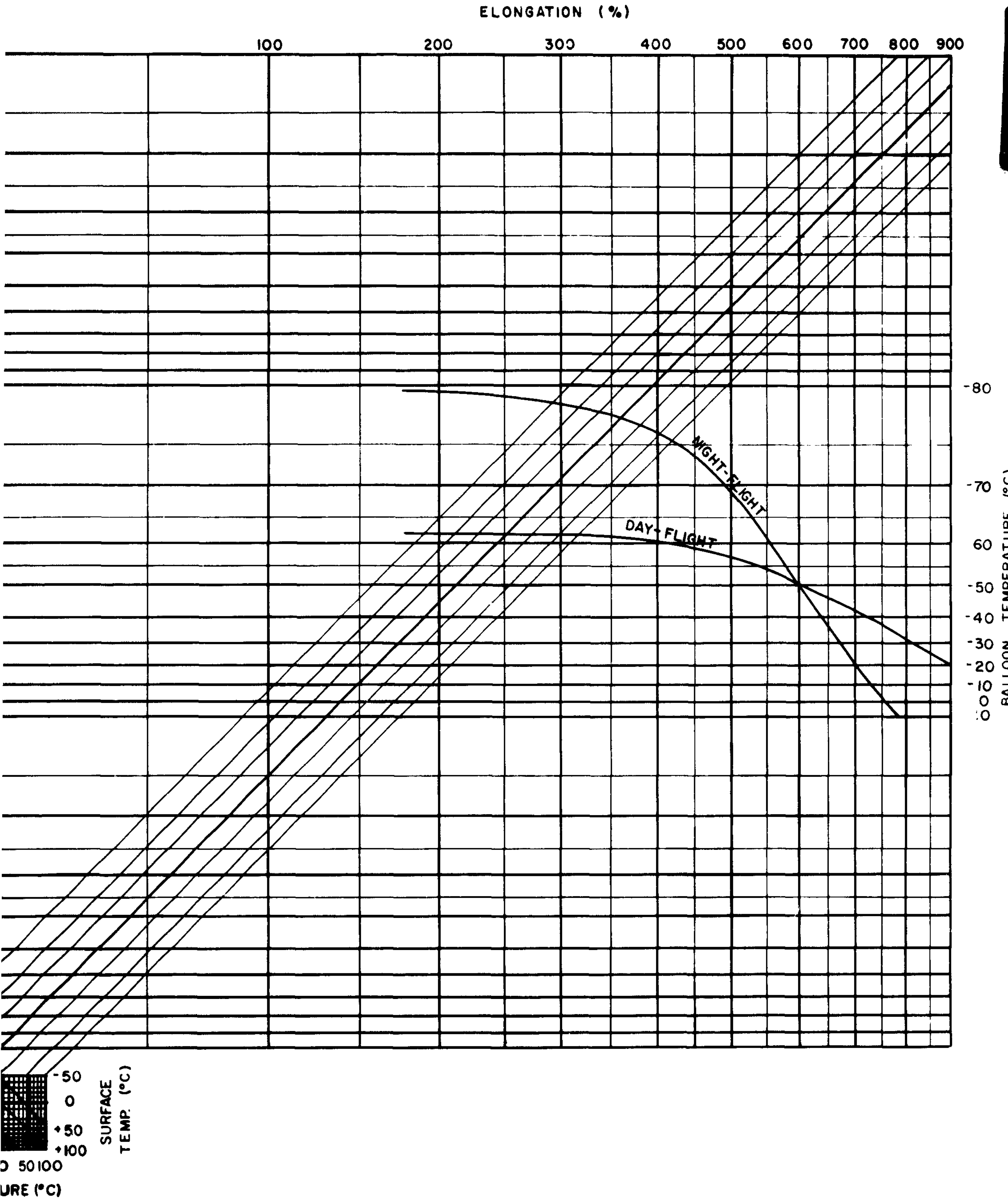
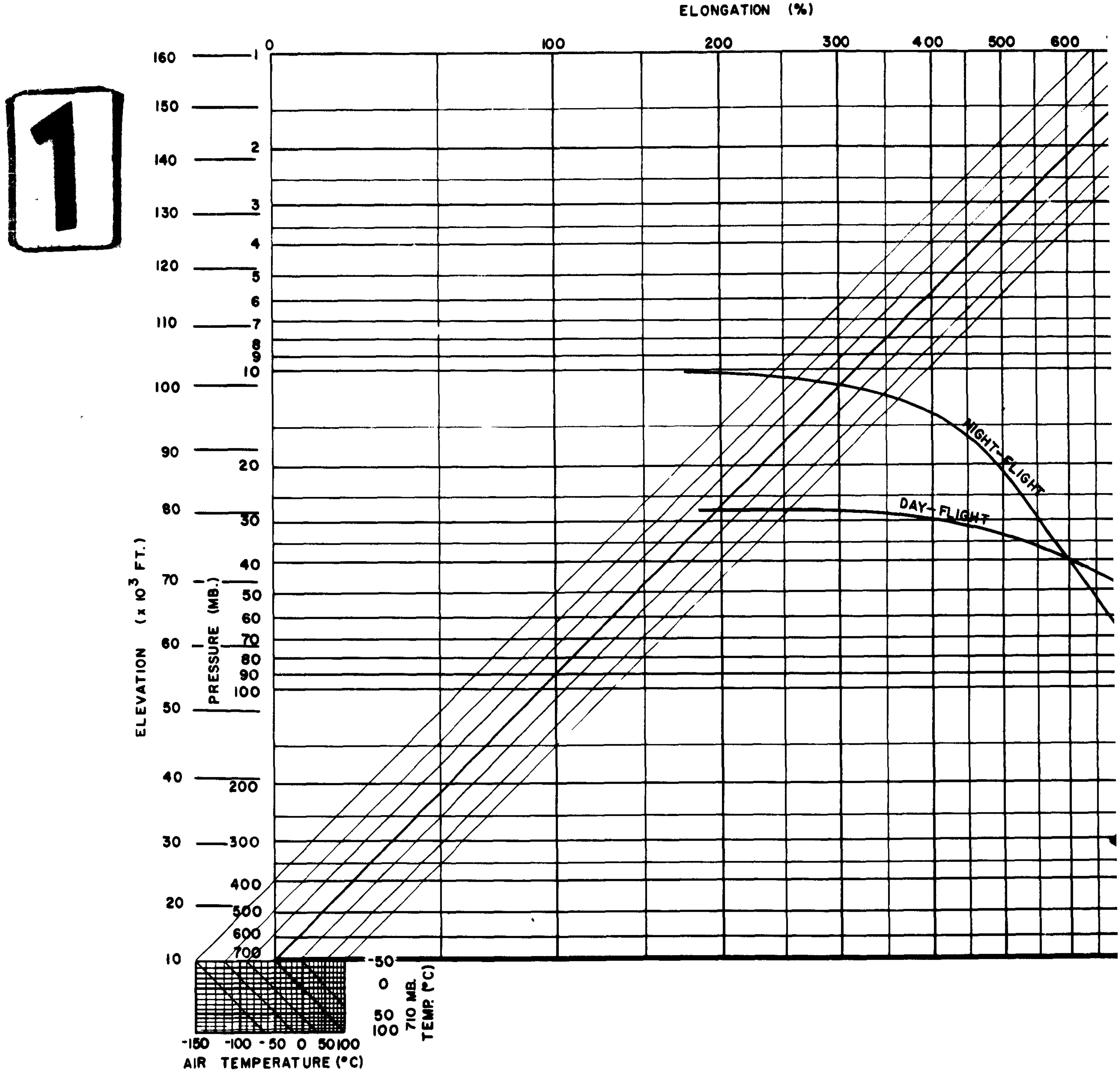
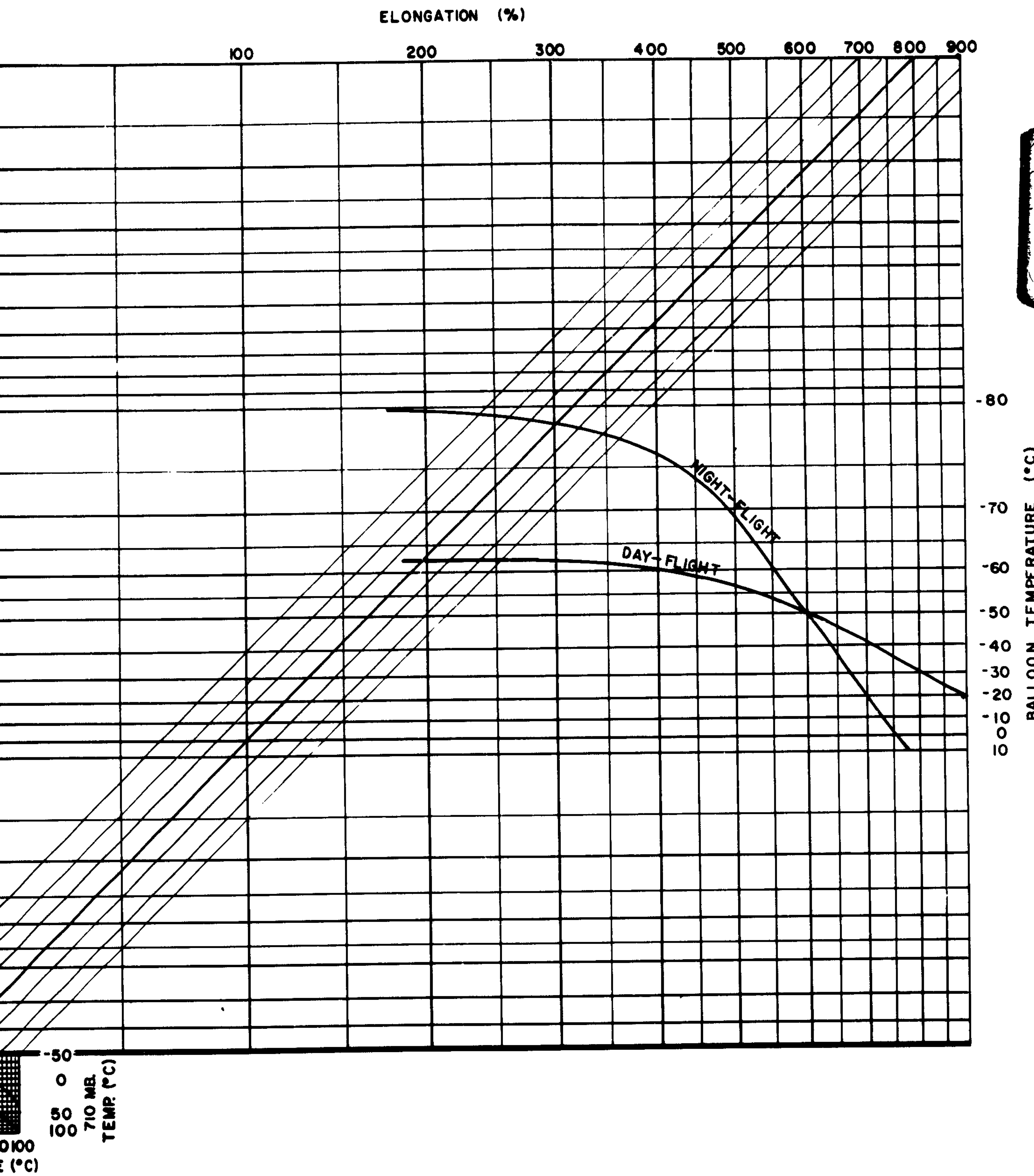

ELONGATION (%)
100
200
300
400
500
600
700
800
900
NIGHT-FLIGHT
DAY-FLIGHT
-80
-70
60
-50
-40
-30
-20
-10
0
0
BALLOON TEMPERATURE (°C)
-50
0
+50
+100
SURFACE TEMP. (°C)
50 100
URE (°C)

FIGURE 38

NOMOGRAM FOR DETERMINATION OF RESIDUAL ELONGATION
OF 1750-GRAM BALLOON



1
ELONGATION (%)
0
100
200
300
400
500
600
ELEVATION (x 10³ FT.)
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
PRESSURE (MB.)
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
NIGHT-FLIGHT
DAY-FLIGHT
-50
0
50
100
710 MB. TEMP. (°C)
-150
-100
-50
0
50
100
AIR TEMPERATURE (°C)



ELONGATION (%)
100
200
300
400
500
600
700
800
900
-80
-70
-60
-50
-40
-30
-20
-10
0
10
BALLOON TEMPERATURE (°C)
NIGHT-FLIGHT
DAY-FLIGHT
-50
0
50
100
710 MB. TEMP. (°C)
0100
E (°C)

3. It has been assumed that the free air temperature is the same as the neoprene fabric temperature. Measurements of internal gas temperature versus ambient air temperature indicate that during day flights above the tropopause, the internal temperature is higher than the ambient air temperature. The difference may occasionally be as high as $40^{\circ}C$ (see later section). These temperatures were measured 6 inches inside the balloon. Also, the balloon fabric is extremely thin and is being ventilated as the balloon is rising at the rate of over 1000 feet per minute. In view of these considerations, the fabric temperature is probably much more nearly the same as the air temperature rather than the gas temperature. In any case, a $40^{\circ}C$ error in gas temperature at an ambient temperature of near $200^{\circ}K$ introduces an error of about 20% or an elongation error of less than 3%. Further, this error will lead to an over estimate of elongation. (The balloon will perform somewhat better than expected.) On the other hand, at night internal gas temperatures are slightly lower than air temperatures so the error introduced is of opposite sign but smaller than the day-time error.
4. The ultimate elongation characteristic curves for the neoprene have been determined empirically under isothermal conditions. It is known that the ultimate elongation characteristics can be improved by pre-elongation. However, not enough information is available on this property to make use of it here. When information becomes available, this can be incorporated into the diagram. In view of the isothermal determination of elongation and the fact that the balloon as it rises into colder temperatures in the troposphere is actually pre-elongating

itself, the ultimate elongation curves give a lower estimate of the ultimate elongation than that which is possible.

5. The variability in the data that comprised the ultimate elongation curves and the variability in the quality control of large balloons (e.g., minute bubbles, etc.), probably introduces a variability of performance greater than that due to atmospheric uncertainty.

As an aid in the use of the nomogram in predicting the expected balloon performance, lapse rates of average atmospheric temperature for 55°N. lat. are presented as Figure 29, for winter (January) and summer (July) conditions. These may be used to get an estimate of average extreme conditions likely to be encountered at this latitude.

Part B: Determination of Dimensions of Fast-Rising Balloons

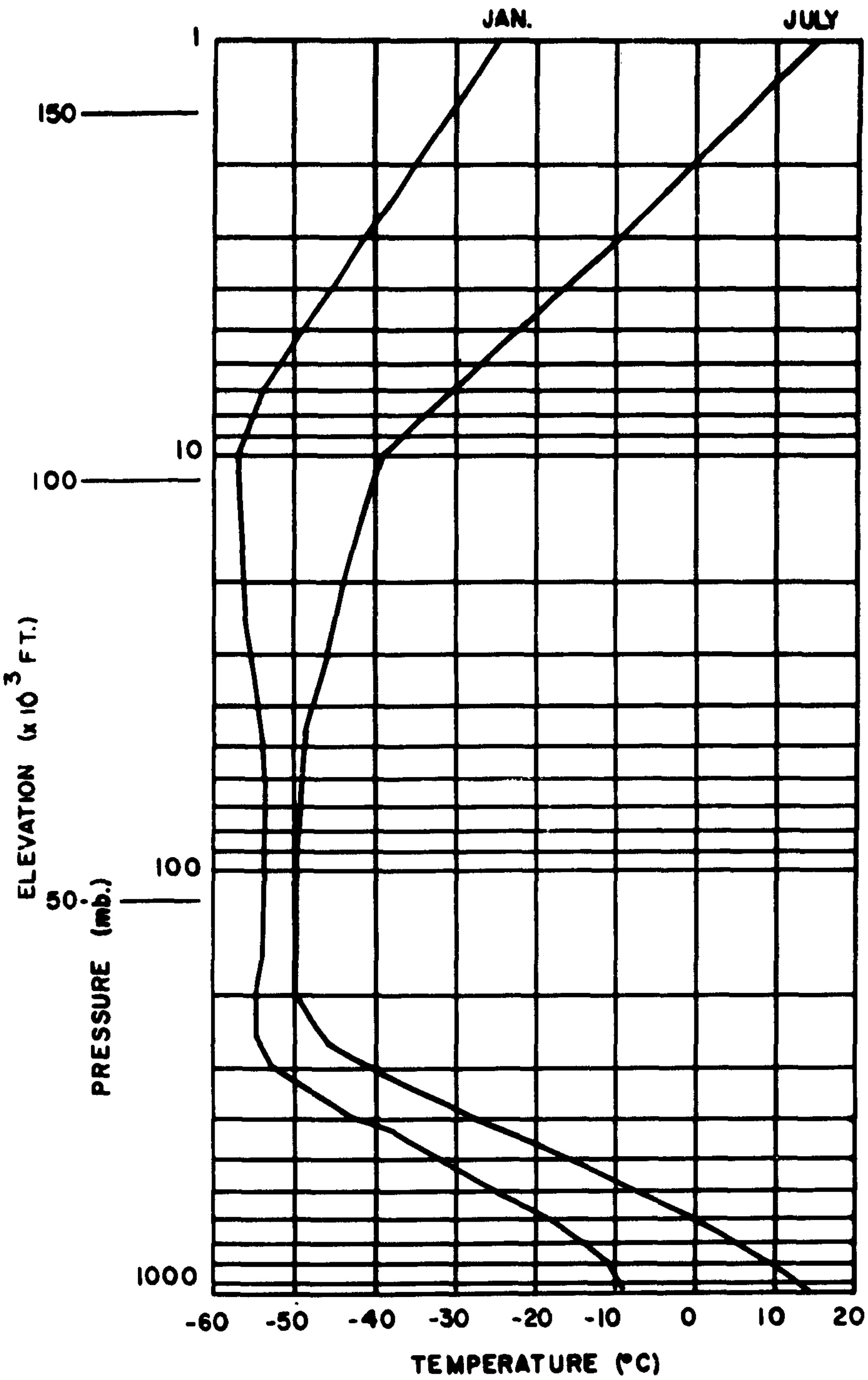
The dimensions of fast-rising balloons designed to reach altitudes of 75,000 and 100,000 feet were theoretically determined.

The performance of an ML-518 balloon was taken as a basis for the following calculations. Such a balloon weighs 800 grams excluding the stem assembly and has a flaccid length of 100 inches. Its gauge ranges from .003" to .0035". When flown with a total lift of 3700 grams, it reaches an altitude of 100,000 feet or more in the daytime.

It has been shown that a fast-rising balloon should have a wall thickness of at least twice and preferably three times that of a standard sounding balloon. Therefore, if the length is maintained at 100 inches, a balloon having a wall thickness of .009" to .010" would weigh 2400 grams, since the weight would be proportional to the thickness.

FIGURE 29

AVERAGE LAPSE RATE CONDITIONS AT 55° N. LAT. FOR JANUARY AND JULY



AVERAGE TEMPERATURE 55° N. LAT.

FACTUAL DATA (continued)

TASK B, Phase 6, Part B (continued)

To this must be added the weight of the tail. If a standard gauge ML-518 type is used for this purpose, an additional weight of 600 grams may be assumed since approximately one quarter of the tail balloon is removed before affixing it to the balloon proper. The weight of the assembly, therefore, would be 3000 grams, which is 2200 grams more than that of an ML-518 balloon.

It is customary to fly this type of fast-rising balloon with a free lift of 2700 grams, which is 1100 grams more than that used to fly an ML-518. Therefore, the total lift required for the balloon described would be 3300 grams greater than that of an ML-518 balloon, or 7000 grams.

The total lift is directly proportional to the volume of gas, and hence the volume of an ML-518 at release can be represented by 3700 K_1, when K_1 is a constant depending on the density of the gas used, converting lift to volume. Assuming the pressure inside a meteorological balloon to be equal to the ambient pressure throughout the flight, then

$$\frac{P_G\ V_G}{T_G} = \frac{P_B\ V_B}{T_B} \qquad (1)$$

where P_G is the ambient pressure at the ground

V_G is the volume of balloon at launch

T_G is the temperature of the gas at launch

P_B is the ambient pressure at burst

V_B is the volume of balloon at burst

T_B is the temperature of the gas at burst

T_G and T_B will show variations from day to day but, in general, these variations will be relatively small and hence it may be assumed that T_G/T_B is a constant. This is, of course, only true providing the altitude at which the balloon bursts is in the range of 60,000 feet to 100,000 feet where the temperature is fairly constant. Equation (1) may, therefore, be rewritten

$$P_G\ V_G = C \cdot P_B V_B \qquad (2)$$

In the case of an ML-518 balloon released at 760 mm pressure and reaching an altitude of 100,000 feet or 8 mm pressure, and having an initial volume of 3700 K_1, the volume at burst is given by

TASK B, Phase 6, Part B (continued)

$$V_B = \frac{P_G\ V_G}{C \cdot P_B} = \frac{760 \cdot 3700\ K_1}{C \cdot 8} \qquad (3)$$

The streamlined balloon described has initially the same flaccid volume as an ML-518 and will, therefore, burst at the same volume, V_B. However, the initial volume of gas used for this balloon is 7000 K_1. Hence, from equation (2)

$$P_B = \frac{P_G\ V_G}{C \cdot V_B} = \frac{760 \cdot 7000\ K_1}{C \cdot V_B} \qquad (4)$$

Substituting for V_B from equation (3)

$$P_B = \frac{760 \cdot 7000\ K_1 \cdot C \cdot 8}{C \cdot 760 \cdot 3700\ K_1} = 15.1 \text{ mm}$$

This pressure corresponds to an altitude of 86,000 feet. Therefore, a lighter, shorter balloon should be capable of reaching an altitude of 75,000 feet.

A reduction in the weight of this balloon by 800 grams would result in an assembly weight of 2200 grams and a total lift of 6200 grams. In order to retain the same wall thickness, it would be necessary to reduce the length of the balloon. The weight of the balloon proper has been reduced from 2400 grams to 1600 grams, and the weight is proportional to the area of the balloon film which is proportional to the square of the length. Therefore, if L_2 is the new length

$$L_2^2 = \frac{1600}{2400}\,(100'')^2 \quad \text{and } L_2 = 81.6 \text{ inches}$$

The volume at burst of a 100-inch balloon is given by

$$V_B = \frac{760 \cdot 3700\ K_1}{C \cdot 8} \quad \text{(equation 3)}$$

Hence, the volume of a balloon 81.5 inches long is given by

$$V_B\ 81.5 = \frac{760 \cdot 3700\ K_1}{C \cdot 8}\left(\frac{81.5^3}{100^3}\right)$$

Therefore, from equation (4) the pressure at burst of such a balloon flown with a total lift of 6200 grams is given by

$$P_B\ 8.15 = \frac{760 \cdot 6200\ K_1}{C} \times \frac{C \cdot 8}{760 \cdot 3700\ K_1} \times \frac{100^3}{81.5^3} = 24.9\ \text{mm}$$

This corresponds to an altitude of 76,000 feet.

Therefore, a balloon assembly weighing 2200 grams of which 600 grams constitutes a streamlined tail assembly and having a flaccid length of approximately 80 inches should reach an altitude of 75,000 feet when flown with a total lift of 6200 grams.

The above figures are based on the performance of a day-flight balloon. In order to achieve the same results at night, the performance of an ML-537 can be taken as a basis. This balloon may be considered as weighing 1000 grams and having a flaccid length of 110 inches.

The corresponding fast-rising balloon would, therefore, weigh 3000 grams and would carry a tail weighing 750 grams. Such an assembly flown with a free lift of 2700 grams and carrying a standard radiosonde would have a total lift of 7750 grams, compared with 3900 grams total lift for an ML-337.

Substituting in equation (3)

$$V_B = \frac{760 \cdot 3900\ K_1}{C \cdot 8}$$

Therefore,

$$P_B = \frac{760 \cdot 7750\ K_1 \cdot C \cdot 8}{C \cdot 760 \cdot 3900\ K_1} = 16.3\ \text{mm}$$

This corresponds to an altitude of 85,000 feet.

A similar reduction in weight as was described for the day-flight balloon would reduce the weight of the balloon proper to 2000 grams, and in order to maintain the wall thickness, the length would have to be reduced to

$$L_3 \text{ where } L_3^2 = \frac{2000}{3000}(110)^2 \text{ and } L_3 = 89.8$$

Following the same reasoning as for the day-flight balloon

$$V_{B\ 89.8} = \frac{760 \cdot 3900\ K_1}{C \cdot 8} \left(\frac{89.8^3}{110^3}\right)$$

Therefore,

$$P_{B\ 89.8} = \frac{760 \cdot 6750\ K_1}{C} \times \frac{C \cdot 8}{760 \cdot 3900\ K_1} \times \frac{100^3}{89.8^3} = 19.2\ \text{mm}$$

This corresponds to an altitude of 81,000 feet.

Therefore, a balloon assembly weighing approximately 2800 grams, of which 750 grams constitutes a tail assembly, and having a flaccid length of approximately 90 inches, should reach an altitude of at least 75,000 feet when flown with a total lift of 6750 grams.

The figures thus determined are very close to those specified for the ML-541 balloon which is required to reach 75,000 feet in the daytime, and for the ML-550 balloon which is required to reach this altitude at night. It appears, therefore, that the basis of calculation is quite sound.

In the case of a balloon designed to reach altitudes of 100,000 feet at 1700 feet per minute, the ML-564 may be taken as a basis for calculation. This is a dual-purpose balloon, but experience has indicated that a day-flight balloon weighing 1500 grams and having a flaccid length of 140 inches will reach an altitude of 120,000 feet.

Hence, if the wall thickness is tripled and a tail consisting of a thin-walled ML-564 type with the top cut away and weighing 1100 grams is attached, an assembly weighing 5600 grams will be obtained. Such a balloon flown with a free lift of 3000 grams would require a total lift of 9900 grams. This compares with a total lift of 4400 grams for a 1500-gram balloon.

Following the same reasoning as previously, from equation (3)

$$V_{B\ 564(\text{day})} = \frac{760 \cdot 4400\ K_1}{C \cdot 3.24}$$

and substituting the appropriate values in equation (4)

$$P_B = \frac{760 \cdot 9900\ K_1 \cdot C \cdot 3.24}{C \cdot 760 \cdot 4400\ K_1} = 7.3\ \text{mm}$$

FACTUAL DATA (continued)

TASK B, Phase 6, Part B (continued)

This corresponds to an altitude of 102,000 feet.

Hence, a day-flight, fast-rising balloon required to reach an altitude of 100,000 feet should have an assembly weight of 5600 grams and a flaccid length excluding the tail of 140 inches.

The standard ML-564 balloon designed to fly at night weighs 1800 grams and has a flaccid length of 150 inches. Therefore, the thick-walled balloon would weigh 5400 grams, and with the tail assembly it would weigh 6750 grams. Such a balloon would require a total lift of 11,000 grams, as compared with a total lift for the ML-564 of 4700 grams.

Therefore,

$$V_{B\ 564} = \frac{760 \cdot 4700\ K_1}{C \cdot 3.24}$$

and

$$P_B = \frac{760 \cdot 11{,}000 \cdot C \cdot 3.24}{C \cdot 760 \cdot 4700\ K_1} = 7.6\ \text{mm}$$

This corresponds to an altitude of 101,000 feet.

Summarizing the above results and also determining the length of the total balloon assembly, the following physical characteristics are obtained for the four required balloons:

Altitude (feet)	Day/Night Flight	Weight (grams)		Length (inches)	
		Balloon	Assembly	Balloon	Assembly
75,000	Day	1600	2200	80	135
75,000	Night	2000	2800	90	150
100,000	Day	4500	5600	140	205
100,000	Night	5400	6750	150	220

Part C: Determination of Physical Properties of Constant-Level Balloon Films

Under normal applications, a neoprene balloon which has been inflated to have positive bouyancy when launched will rise in the atmosphere and expand as it rises. This will continue until the internal pressure causes the ultimate elongation of the neoprene film to be exceeded at some point on its surface. At this point, the balloon is ruptured.

On the other hand, if the modulus of the neoprene is such that the tension in the balloon increases rapidly as the balloon expands, it is entirely possible for the situation to develop in which the increased tension prevents further expansion of the balloon. The balloon will then float at this level of zero bouyancy.

This condition of zero bouyancy is determined by the interaction of several factors involving characteristics of the neoprene film and the decrease of pressure with altitude in the atmosphere. These will be discussed separately in turn.

1. Modulus of Neoprene Film

On the basis of empirical data presented by us in 1958 (see Final Report of Contract No. DA-36-039-SC-72386, Task A, Phase 3, Parts A and B), the modulus of neoprene balloon film may be expressed approximately by the following relationship:

$$m = a \cdot \exp\left(b\frac{E}{100} - c\frac{100}{E} + dT_b\right)$$

where m is modulus in psi

a, b, c, d are constants depending on the sample of neoprene

E is elongation in per cent

T_b is the temperature of the balloon film

In practice, curves have been drawn for various samples of neoprene under many conditions of elongation and temperature. From these data the constants may be evaluated. Further, if one directs attention to elongations greater than 200% or 300%, the term involving E in the denominator of the exponential may be omitted.

Also, considering the temperature to be constant during the stretching of the neoprene, the modulus becomes, approximately:

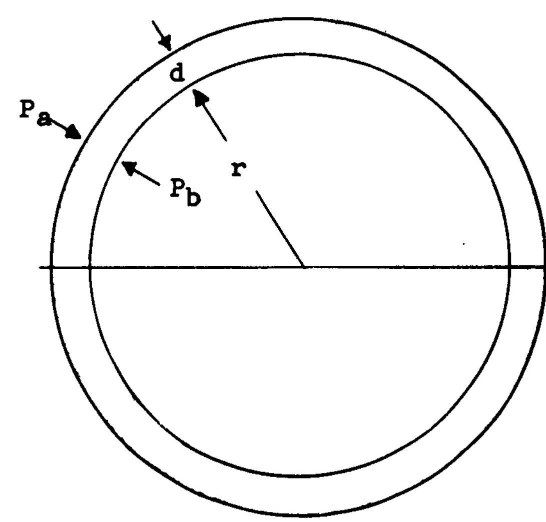
$$m = a \cdot \exp\left(b\frac{E}{100} + c\right) \tag{1}$$

2. Balloon Tension

It is possible to write an expression relating the tension in the balloon film to the elongation, internal pressure, and ambient air pressure. Consider the balloon to be spherical, the balloon film to have uniform thickness, and the internal pressure to be uniform.

In this development these assumptions are not too serious as the percental deviation of the actual conditions from these idealized ones is not great. However, in a later discussion on the location of the most probable point of rupture of the balloon, it will be shown that the deviation of the shape from spherical and the variation of thickness play an important role in determining where the balloon will burst.

If one were to consider the balloon to be divided into hemispheres, the force tending to separate the two halves is:



$$F_s = (P_b - P_a)A = P_d \pi r^2$$

where

F_s is the force separating the two halves

P_b is internal gas pressure

P_a is ambient air pressure

P_d is $P_b - P_a$

A is the cross section area of the balloon

r is the radius of the balloon

The tension in the balloon film holding the two hemispheres together is the same as F_s and may be expressed in terms of the modulus as

$$m = \frac{F_s}{A} = \frac{F_s}{2\pi rd}$$

where d is the thickness of the film.

On combining these two expressions,

$$m = \frac{P_d \cdot r}{2d}$$

But r and d may be expressed in terms of elongation and the flaccid conditions of the balloon. Since the volume of the neoprene is conserved as the balloon expands

$$4\pi r^2 d = \text{constant}$$

is a close approximation to the volume of the neoprene. This may be written in terms of elongation and flaccid conditions as

$$r = \left(\frac{E + 100}{100}\right) \cdot r_f$$

and

$$r_f^{\,2} \cdot d_f = r \cdot d$$

where r_f and d_f are the flaccid radius and thickness, respectively. Then

$$m = \frac{P_d \left(\frac{E + 100}{100}\right)^3 r_f}{2\ d_f} \qquad (2)$$

3. Internal Balloon Pressure

The pressure of the gas inside the balloon is equal to the sum of the ambient air pressure and the pressure difference due to the tension in the balloon film. This may be expressed as

$$P_b = P_a + P_d \qquad (3)$$

FACTUAL DATA (continued)

TASK B. Phase 6. Part C (continued)

Since the gas inside the balloon behaves essentially as an ideal gas, the pressure P_b may be expressed in terms of the elongation and initial pressure by means of the gas law.

$$P_b = \frac{P_o\ T\ (E_o + 100)^3}{T_o\ (E + 100)^3} \tag{4}$$

where P_o is the balloon pressure at the ground when inflated to the desired free lift

T_o is the gas temperature at the ground in ^oK

T is the gas temperature when elongation is E also in ^oK

E_o is initial elongation at the ground

E is elongation at the level in question

4. Balloon Bouyancy

The net bouyancy of the balloon is just the difference between the weight of the balloon (neoprene, gas, and load) and the weight of the volume of air displaced. That is

$$B = \frac{4}{3}\pi\left(\frac{E+100}{100}\right)^3 r_f{}^3 \rho_a g - \frac{4}{3}\pi\left(\frac{E+100}{100}\right)^3 r_f \rho_g g - (M_b+M_R)g \tag{5}$$

where B is the net bouyant force

ρ_a is the ambient air density

ρ_g is the balloon gas density

M_b is the mass of neoprene balloon film

M_R is the mass of load carried by the balloon

g is acceleration of gravity

5. Ambient Air Density

The ambient air density that appears in the equation above and P_a are independent parameters which depend upon the environment only. Consequently, these data must be supplied by the atmosphere or approximated by some set of standard conditions.

FACTUAL DATA (continued)

TASK B, Phase 6, Part C (continued)

6. The determination of conditions for zero bouyancy

It is possible through the use of equations (1) through (5) to derive the conditions under which zero bouyancy will be encountered. If one has the curve of modulus vs. elongation and temperature for a given neoprene compound, the flaccid and initial characteristics of the balloon, and the ambient pressure-temperature-height curve for the atmosphere, these five simultaneous equations may be solved to yield the level of zero bouyancy. Conversely, if the elevation (or pressure) of zero bouyancy is given, the desired modulus-elongation relation may be determined.

One method for the solution of this problem is indicated by the following illustration:

It is required that a Kaysam 8DS (800-gram) balloon float at an elevation of approximately the elevation of 10 mb. What must the modulus be in order to provide zero bouyancy at this elevation?

The balloon constants for this flight are:

M_b = 800 grams	$d_f = 3\text{x}10^{-3}$ inches	$T_o = 273^oK$
M_R = 1250 grams	r_f = 30 inches	P_a = 10 mb.
P_{ao} = 1000 mb.	r_o = 35.4 inches	$T = 223^oK$

1) Find E_o

$$\frac{r_o}{r_f} = 1.18; \quad E_o = 18\%$$

2) P_d at the ground, assuming modulus for E = 18 is 100 psi

use equation (2)

$$P_d = \frac{2m\ d_f}{(E+100)^3 r_f} = \frac{2 \times 100 \times 3 \times 10^{-3}}{(1.18)^3 \times 30} = 12.2 \times 10^{-3} \text{ psi}$$

3) Find P_{bo}

use equation (3)

$$P_{bo} = P_{ao} + P_{do} = 14.7 + .012 = 14.712 \text{ psi or } 1000 \text{ mb.}$$

FACTUAL DATA (continued)

TASK B, Phase 6, Part C (continued)

4) The determination of E at the 10 mb. level:

At this elevation, since the balloon is to float, B = 0. One may now use equation (5) to determine the radius of the balloon. To do this, it is first necessary to determine the mass of the hydrogen in the balloon. This may be determined from the size of the balloon and the internal pressure at the ground. From the gas law:

$$\rho_g = \frac{p}{RT} \quad \text{or} \quad M_g = \frac{Vp}{RT}$$

where $V = 109\ ft^3 = 3.08\ m^3$

$p = 1000$ mb.

$R = 4.157 \times 10^7$

$T = 273$

$$M = \frac{3.09 \times 10^6 \times 10^6}{4.157 \times 10^7 \times 2.73 \times 10^2} = 271 \text{ gm}$$

Now, using equation (5)

$$\frac{4}{3}\pi r^3 \rho_a g = (800 + 271 + 1250)g = 2321\ g$$

But at 10 mb, $T = 223^\circ$

$$\rho_a = \frac{10^6}{2.87 \times 10^6 \times 2.23 \times 10^2} = 1.56 \times 10^{-5} \text{ gm cm}^{-3}$$

Therefore,

$$r^3 = \frac{2321 \times 3}{4\pi \times 1.56 \times 10^{-5}} = 3.55 \times 10^7 \text{ cm}^3$$

$r = 328$ cm = 129 inches

and since $r_f = 30$ inches

$$\frac{r}{r_f} = \frac{129}{30} = 4.3 \qquad \text{and } E = 330\%$$

FACTUAL DATA (continued)

TASK B, Phase 6, Part C (continued)

5) The determination of P_d at 10 mb.

using equation (4)

$$P_b = 10^3 \times \frac{223}{273} \times \frac{(1.18)^3}{(4.3)^3} \times 16.9 \text{ mb.}$$

and by equation (3)

$$P_d = 16.9 - 10 = 6.9 \text{ mb} = .102 \text{ psi}$$

6) The determination of the modulus at 10 mb:

The modulus required for an elongation of 330% to produce this pressure difference of .102 psi may be determined by using equation (2)

$$m = \frac{.102 \times (4.3)^3}{2} \times \frac{30}{3 \times 10^{-3}} = 4.04 \times 10^4 \text{ psi}$$

This corresponds to about 9400 psi as determined in the dumbbell test.

Part D: Analysis of Stress in Sounding Balloons

It is apparent that in order to predict the behavior of a balloon as it expands in flight, it is necessary to have an understanding of the stresses generated in the balloon film as it rises in the atmosphere. These stresses may be characterized as mechanical and thermal. The thermal properties (including radiation) of the atmospheric environment and of the balloon have been discussed in part previously under, Task B, Phase 3. This section will deal with an analysis of what happens mechanically as the balloon expands and bursts.

As a first approach to the stress problem, one may investigate the most likely point of rupture on the balloon surface as the balloon expands to its ultimate elongation. If it is found to clearly be at one consistent portion of the surface of the balloon, the opportunity then affords itself to strengthen the balloon at that location and consequently improve its performance.

Visual observations of radiosonde balloons in flight indicate that the balloon assumes a nearly spherical shape as it approaches its ultimate elongation. However, it is impossible to see where the first rupture occurs. The balloon seems to shatter all over at the same time.

FACTUAL DATA (continued)

TASK B, Phase 6, Part D (continued)

Consider the balloon to be a sphere of uniform thickness with the radiosonde weight suspended from a point at the lower (south) pole of the sphere. Further, if the balloon is to maintain its lift up to the bursting level, it is necessary that the modulus of the neoprene be small enough at the elongations encountered so that the balloon is essentially free to expand even at extreme altitudes.

In this connection, the report dealing with neoprene constant pressure-altitude balloons (see Task B, Phase 6, Part C) indicates that this is a necessary condition. Otherwise, the balloon will stop expanding and will tend to find some level of equilibrium at which it will float. This condition implies that for a freely rising balloon, the pressure difference between the internal gas and the ambient air must be near zero.

Under these conditions, the forces acting on the balloon film are bouyancy; the weight of the neoprene, the tension due to the elongation of the neoprene, and the weight of the radiosonde instrument. If the balloon were perfectly spherical and homogeneous, then the only force applied at a single point and consequently capable of exerting the maximum tension on the balloon film would be the radiosonde weight. Since the balloon surface is horizontal at this point, the tension required to support the weight of the radiosonde would become infinitely great. The south pole of the balloon would then be the weakest point on the surface of the balloon.

In practice, however, the balloon is not perfectly spherical. Nor is it exactly uniform in thickness or composition. This is immediately apparent as one observes the distortions in a balloon as it is being inflated. The shape of the balloon becomes somewhat like an inverted teardrop. The cone of the neck tapers down to nearly a cylinder where the radiosonde is attached. The force of bouyancy also stretches the top so that the vertical dimension of the balloon is much larger than the horizontal. The fact that the neck of the balloon is elongated reduces the tension in the film at that point and permits the weight to be supported.

In view of these actual distortions of the balloon shape from spherical, it is suggested that a series of experiments be conducted to determine the actual growth shape of the balloon and to determine the breaking characteristics of the balloons. These experiments should simulate flight conditions as closely as possible. This could be

accomplished by inflating a captive balloon to the prescribed bouyancy and then continuing to inflate the balloon with air so that the bouyancy does not change until the balloon bursts.

By observing the location where the balloon bursts, one may find the weakest point on the surface or the point of maximum stress requiring the greatest reinforcement. If this weakest point consistently appears at one preferred location, then this would clearly indicate the part to be strengthened. This procedure would also be desirable in connection with a mathematical analysis of the stresses in that it would provide an objective verification of the theory.

Since the breaking of the balloon occurs in the order of time of a millisecond, ordinary visual observation is inadequate to determine where the break first occurred. To accomplish this, a photographic technique must be used. In this connection, an electronic flash lamp was designed and constructed.

In theory, the operation of the flash is as follows: A sensitive microphone is placed in contact with the neck of the balloon. When the balloon bursts, the shock of the taut neoprene film rupturing is transmitted through the film to the microphone. An electrical signal from the microphone is amplified and transmitted to a special trigger circuit. This impulse is shaped so that the electronic flash lamp may be flashed. The experiment is carried out in darkness so that a camera with its shutter open will record the image of the balloon in the light of the flash lamp.

Figure 30 is a photograph of the electronic components of the equipment used. The microphone is at the lower left in the photograph. This is connected to the amplifier located just above it. The trigger circuit is located just above the amplifier. In the lower right of the photograph is the power supply which generates the 3000 volts DC required to charge the flash capacitor. The capacitor and lamp are above the high voltage power supply. A Polaroid Model 110B camera was used to make the exposures.

Since the time delay of the electronic pulse is of the order of micro-seconds, the longest delay involved is the transmission of the shock wave in the neoprene from the point of rupture to the microphone. To test the capability of this equipment to actually photograph the breaking of the balloon, an exposure was made using a 10-gram balloon inflated with air. The microphone was attached to the neck of the balloon, and the film was ruptured by burning its surface. The result of this experiment is indicated in Figure 31.

FACTUAL DATA (continued)

TASK B, Phase 6, Part D (continued)

It is evident from this figure that it is possible to photograph the breaking of a balloon soon enough after the break has occurred so that the location of the break can be recorded.

Another experiment in which a 30-gram balloon was inflated with helium until it burst spontaneously is shown in Figure 32. This illustrates that the break occurred near the equator of the balloon.

A series of experiments was now initiated to determine whether there is a preferred location of breaking of the balloon while it is being inflated under the tension of a load attached to the neck of the balloon. This was done to stimulate the expansion of a balloon in free flight as it rises while carrying aloft a radiosonde. In this manner it can be determined whether or not there is a particular consistently weak point on the balloon.

At the same time, it was desired to determine the manner in which the balloon is distorted while expanding. This would reveal inhomogenieties in the manufacture of the balloon and would also give an insight into the rate of rise of the balloon which is a function of the shape of the balloon.

A further purpose of these experiments was to test the flashlighting equipment already described. It was apparent that a single camera might not always be in a position to clearly record the actual breaking of the balloon surface. To overcome this deficiency, two Polaroid cameras were set up as indicated in Figure 33.

The cameras were approximately 15 feet from the balloon and diametrically opposite each other. The light source was also about 15 feet from the balloon. The cameras in Positions 2a and 2b were oriented 90° from the line of illumination.

Three 30-gram balloons were used. Each was inflated with helium until it spontaneously burst. The rupture of the film caused the exposure to be recorded simultaneously on each of the two cameras. The results of the experiments are shown in Figures 34 (a,b) and 35 (a,b). Each of these corresponds to camera positions 2a and 2b, 3a and 3b, and 4a and 4b, respectively in Figure 33.

FIGURE 30

EQUIPMENT USED IN PHOTOGRAPHING BALLOONS AT BURST

FIGURE 31

DEMONSTRATION OF OPERATION OF EQUIPMENT

FIGURE 32

BURSTING PATTERN OF 30-GRAM BALLOON INFLATED WITH HELIUM

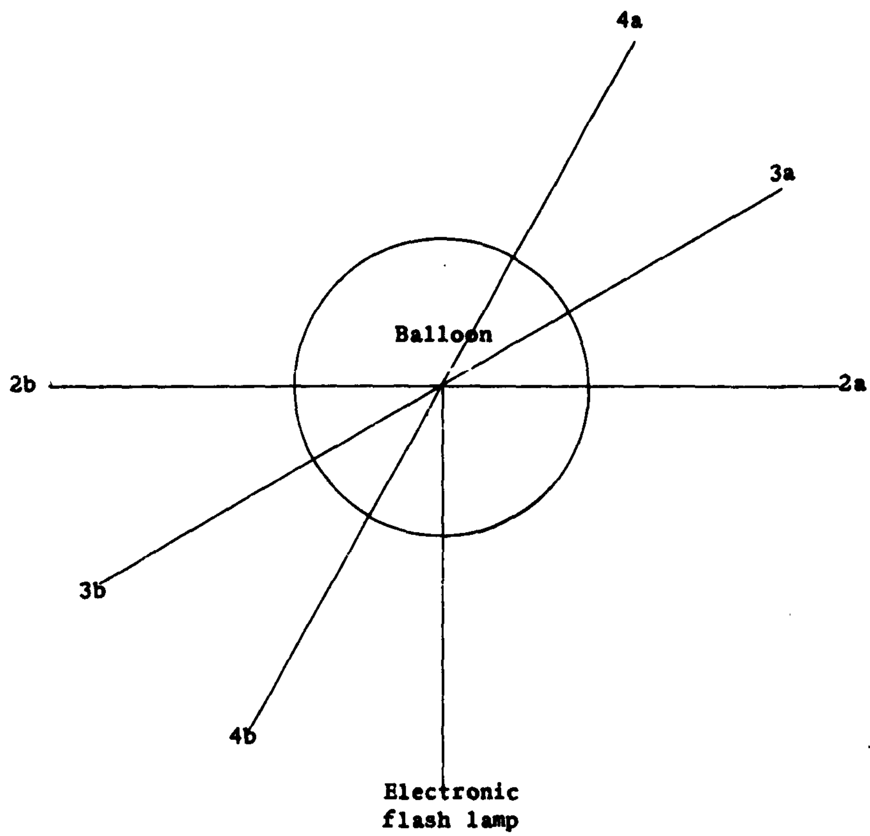


FIGURE 33

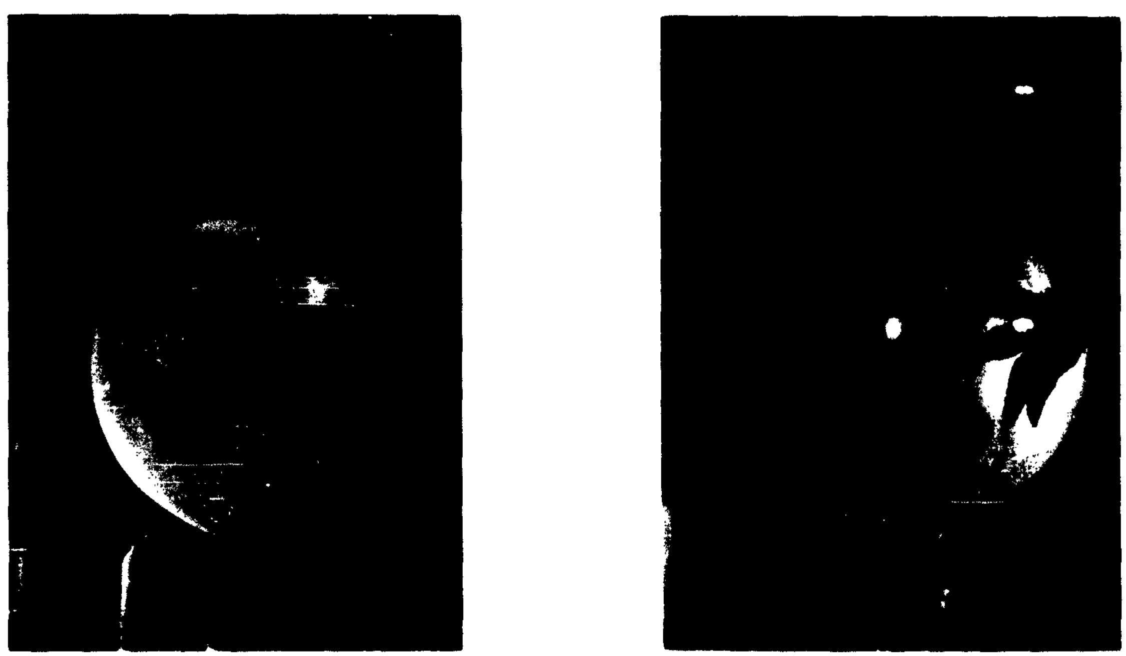
PLAN VIEW OF THE SETUP FOR PHOTOGRAPHING THE BREAKING OF A BALLOON WITH TWO CAMERAS SIMULTANEOUSLY

Camera positions indicated at locations 2(a,b), 3(a,b), and 4(a,b)

BURSTING PATTERN OF 30-GRAM BALLOONS INFLATED WITH HELIUM

(a) (b)

FIGURE 34A



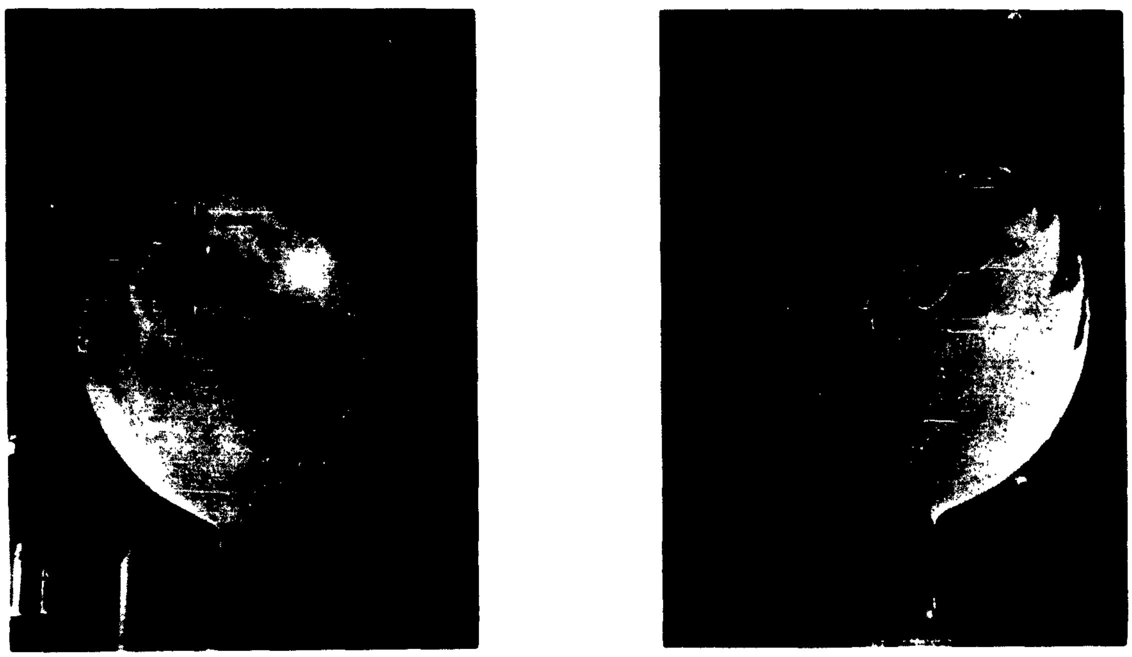
(a) (b)

FIGURE 34B

FACTUAL DATA (continued)

TASK B, Phase 6, Part D (continued)

BURSTING PATTERN OF 30-GRAM BALLOON INFLATED WITH HELIUM



(a) (b)

FIGURE 35

FACTUAL DATA (continued)

TASK B, Phase 6, Part D (continued)

The three sets of photographs indicates that the breaking of the balloon can indeed be photographed simultaneously by two cameras in such a manner that the location of the initial rupture is clearly evident in one of the pictures. In Figures 34A and 34B, the break occurred near the widest part of the balloon. In Figure 35 the break was near the top in the region of maximum deformation, indicating a weakness in that region.

Several other factors of importance are also indicated by the photographs:

(1) Each of the three balloons expanded extremely regularly during inflation, indicating remarkable homogeniety in thickness and modulus over the surface of the balloon.

(2) The size of the balloon, after correction for parallax as indicated in Figure 36, indicated average diameters of 5.9, 5.2 and 5.5 feet for the balloons in Figures 34A, 34B and 35, respectively. The fact that balloons in Figures 34B and 35 were inflated more rapidly than that in Figure 34A probably contributed to their earlier rupture since the helium would have been colder. Even so, all three balloons far exceeded the nominal specification of 3.5 feet at burst.

Part E: Effect of the Modulus Elongation Characteristics on the Shape of Inflating Balloons

It is generally and correctly assumed that a balloon having a higher modulus film will probably have a better shape on inflation than a balloon made from a lower modulus film. However, there have been certain notable contradictions to this rule, and balloons made from or incorporating substantial amounts of the high-modulus polymers, Neoprene 400 and Lytron 615, showed extremely poor shape on inflation.

Since loss of sphericity results in a decrease in ascensional rate, it is highly desirable to gain an understanding of the reasons for such change in shape during inflation, particularly in the case of fast-rising balloons.

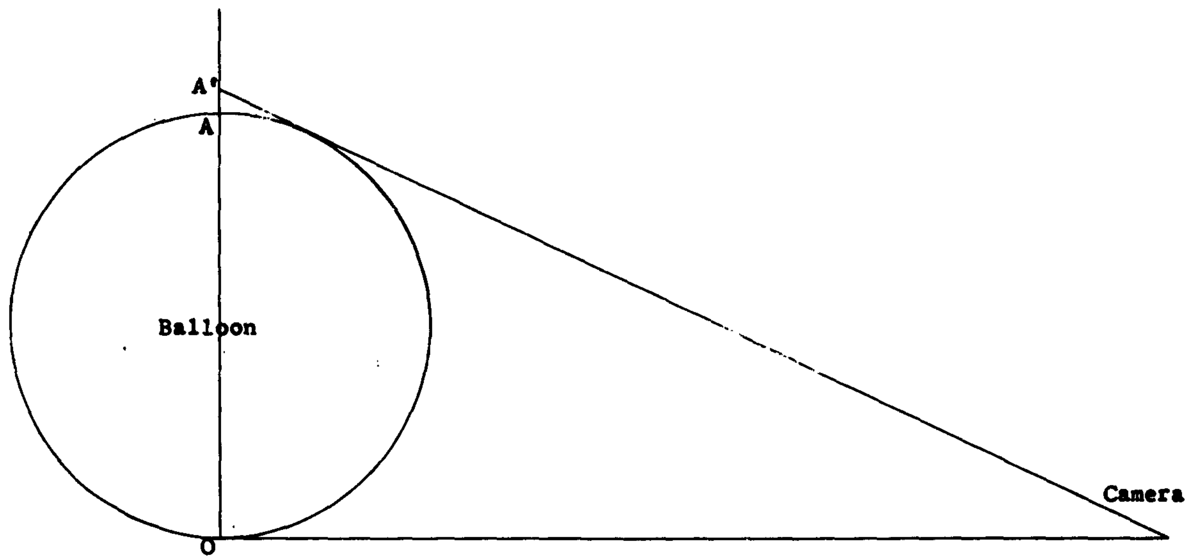


FIGURE 36

EFFECT OF PARALLAX ON THE APPARENT SIZE OF THE BALLOON

Distance of balloon from camera about 15 feet;
OA real diameter; OA' apparent diameter;
Error is approximately 4%

FACTUAL DATA (continued)

TASK B, Phase 6, Part E (continued)

Six 100-gram balloons were made from compound A3-105. Of these, two were not cured, two were cured for 90 minutes at 280°F, and two were cured for 90 minutes at 125°F. Two 100-gram balloons were also made from compound A3-106, and these were also cured for 90 minutes at 280°F.

Physical properties were determined at room temperature, using one of each of the four pairs of balloons, the modulus being recorded at every 50% elongation interval. Instead of tabulating these figures, the results were plotted to yield a modulus-elongation curve, and the results of these tests are given in Figure 37.

A study of these curves shows that in each case there is a point of inflection and a section of the curve where the elongation increases with a relatively small increase in modulus. In the case of the uncured balloon, this is very slight, and the slope of the modulus elongation curve is steep throughout.

In the case of the balloon cured for 90 minutes at 125°F the section with a small slope does not extend beyond the 200% line; whereas in the case of the balloons cured for 90 minutes at 280°F, both the balloons made from compound A3-105 and A3-106 show much greater sections of low slope, A3-105 extending to approximately 500% and A3-106 to approximately 550%.

The remaining balloon from each pair was now inflated and the shape observed throughout. The uncured balloon was spherical throughout its inflation and it may, therefore, be assumed that the slope of this curve is always sufficiently high to ensure sphericity.

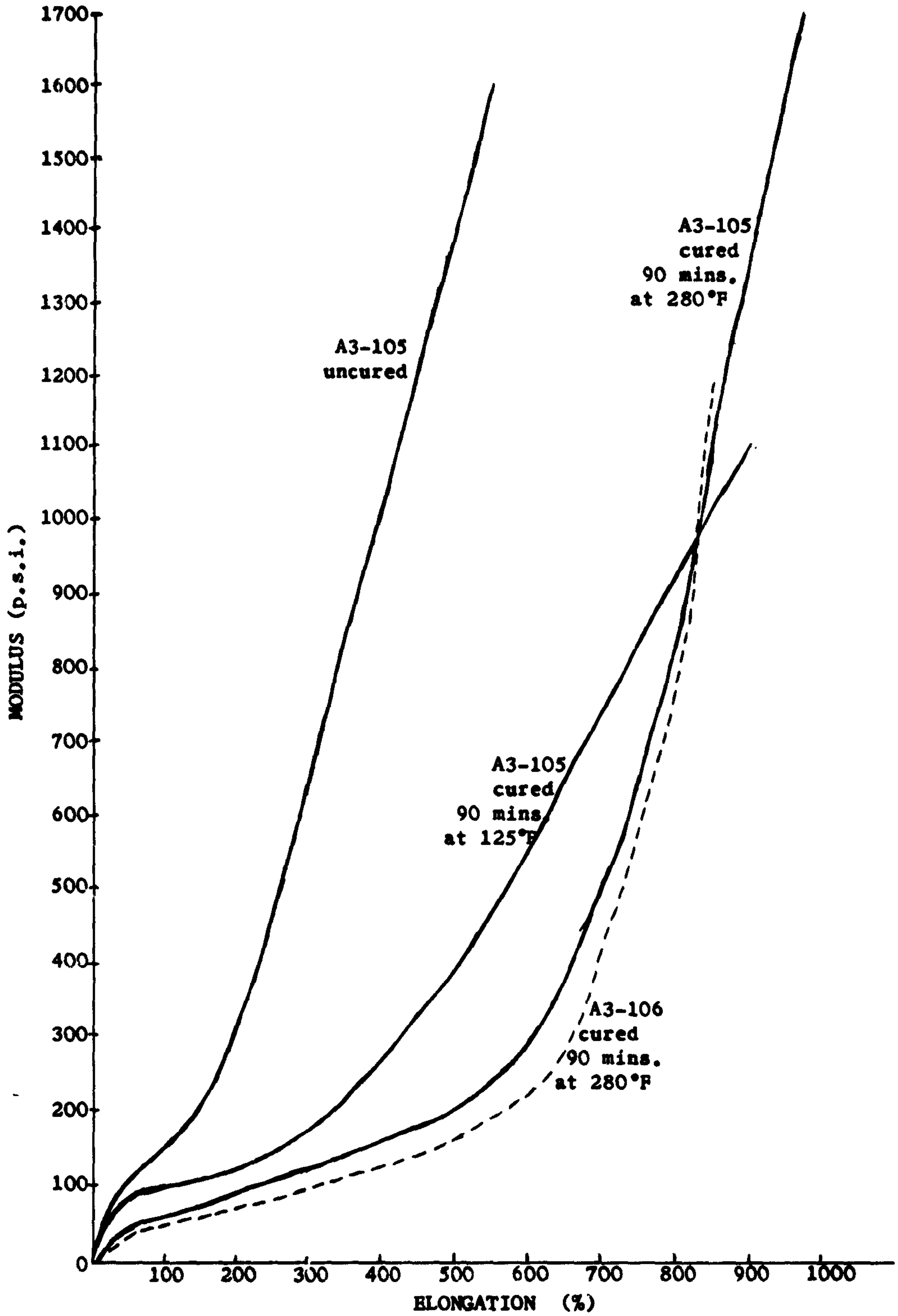
The balloon cured for 90 minutes at 125°F started to blow out of shape at a mean elongation of about 50%. It continued to inflate on one side and began to round out at a mean elongation of approximately 250%, becoming spherical again at an elongation of about 350%.

The two balloons cured for 90 minutes at 280°F, both remained spherical until a mean elongation of about 25% was reached; they then started to blow out of shape, the balloon made from compound A3-106 being somewhat more lopsided than the one made from compound A3-105. Both balloons remained out of shape for about half of the inflation and only began to assume true sphericity at about 600% elongation.

True sphericity is defined here as the time at which the bottom of the balloon is again diametrically opposed to the neck.

FIGURE 37

MODULUS-ELONGATION CURVES OF COMPOUNDS A3-105 AND A3-106
TESTED AT ROOM TEMPERATURE



FACTUAL DATA (continued)

TASK B, Phase 6, Part E (continued)

It is, therefore, apparent that by plotting the modulus-elongation curve, it is possible to predict at what time and to what degree a balloon made from a given compound will blow out of shape during inflation.

Theoretically, if the balloon film is completely uniform in gauge, then there would be no loss of sphericity. Since, however, balloons invariably show some slight variation in thickness, they will tend to stretch at the thinnest section first; and if the slope of the modulus-elongation curve is too small, then substantial deformation will occur.

The slope of the modulus-elongation curve, therefore, is an important measure of the inflation pattern of a balloon and is a further useful tool in compound design.

The above characteristics are based on the room-temperature characteristics and will apply only during the early stages of the flight. However, because of the phenomenon of pre-elongation which redcues the modulus of the film at low temperatures, it can be seen that distortion in the early stages of inflation will result in a variation in modulus at any given elongation throughout the balloon, and the distortion will therefore be maintained or even exaggerated as the temperature falls. There is also liable to be a loss in bursting altitude since the pre-elongated film will show a markedly lower tensile strength than parts of the balloon which are not so stretched before they reach low temperature.

The behavior of compound A3-105 was further investigated at low temperatures. Similar curves were obtained at -20°C and -40°C for uncured balloons as well as for balloons cured for 90 minutes at 125°F and 90 minutes at 280°F. The results are given in Figures 38 and 39.

It can be seen from these graphs that the same point of inflection is shown as at room temperature and that as the cure of the film is increased the magnitude of the effect also increases, the uncured film having the greatest slope throughout.

Therefore, four uncured balloons were submitted for flight testing. In order to provide a wider scope, the balloons were made from compound A3-106, and two were flown by day and two by night. They were all flown with the standard free lift of 1600 grams.

These balloons are identified as EX-3A-696 through EX-3A-699, and their characteristics and flight data are given in Table 198.

FIGURE 38

MODULUS-ELONGATION CURVES OF COMPOUND A3-105
TESTED AT -20°C

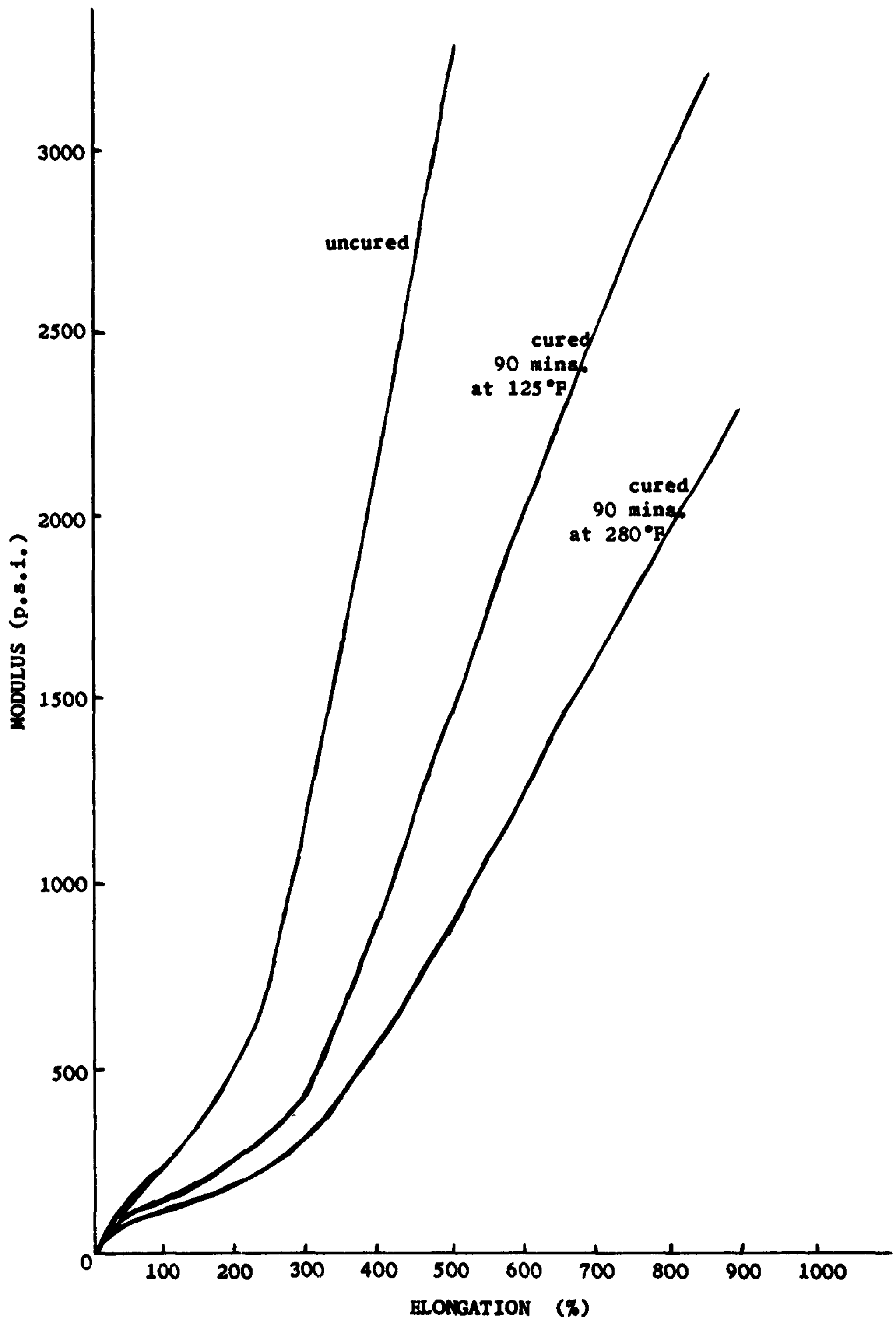


FIGURE 39

MODULUS-ELONGATION CURVES OF COMPOUND A3-105
TESTED AT -40°C

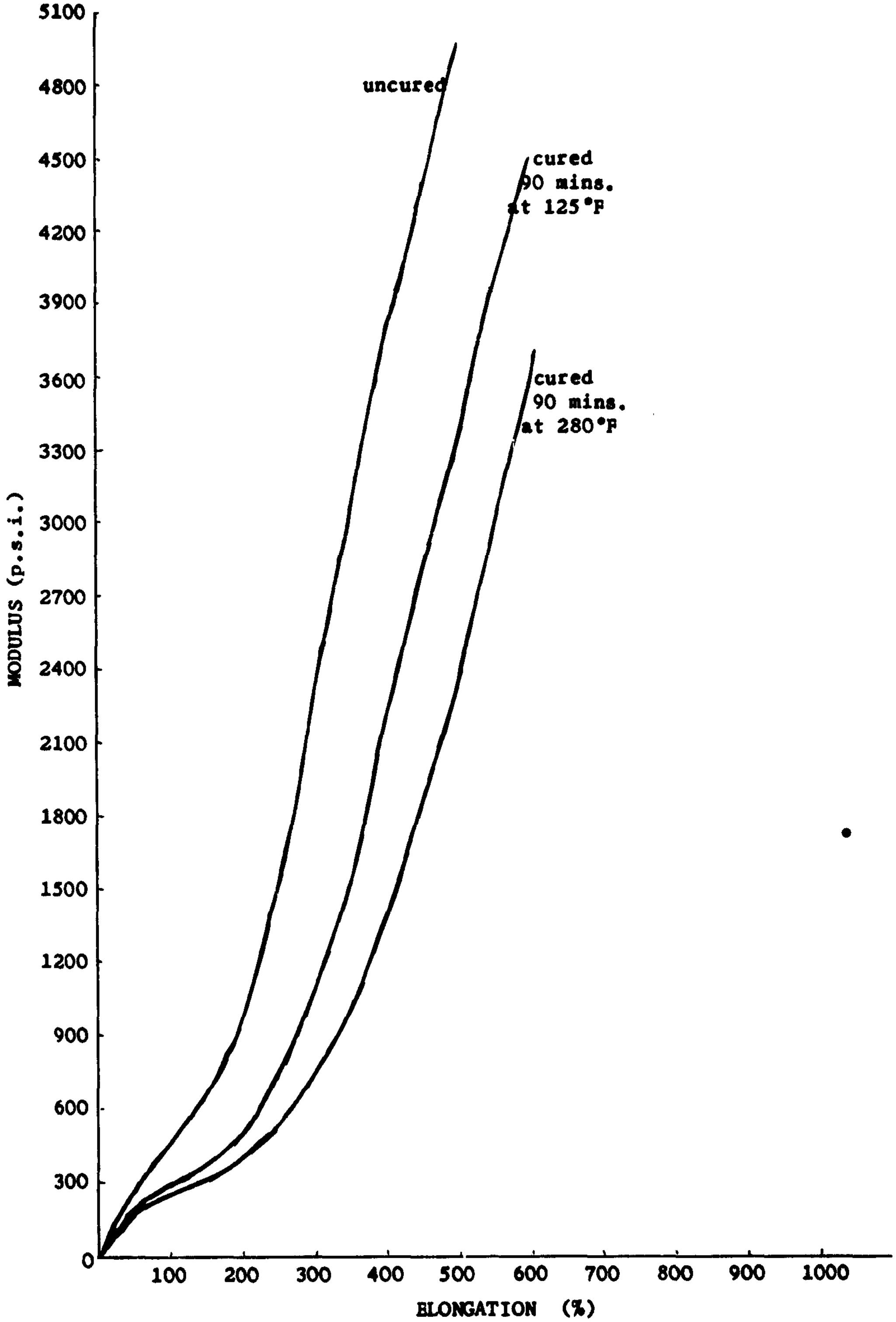


TABLE 198

FLIGHT RESULTS - UNCURED BALLOONS MANUFACTURED FROM COMPOUND A3-106

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-3A-696	C6-3AM	Day	1045	102	76,300	1098
EX-3A-697	C6-5AM	Day	1085	105	79,800	1152
EX-3A-698	C6-6AM	Night	1080	107	88,950	1061
EX-3A-699	C7-3AM	Night	1020	105	102,800	1065

A study of these results shows that, as could be expected, the altitude is much lower than normal for this type of balloon. However, the rate of ascent is in every case in excess of 1000 feet per minute even though the altitudes reached are more than 20,000 feet below normal.

It is well known that balloons of this type almost always increase in rate of ascent at higher altitudes. The fact that the uncured balloons show unusually high rates of ascent over the lower portion of the flight is confirmatory evidence that the balloon is maintaining a more truly spherical shape throughout its flight and that the interpretation of the theoretical data is correct.

FACTUAL DATA (continued)

TASK C: STUDY OF BALLOON CONFIGURATION

Phase 1: Design and Construction of Equipment

The most satisfactory results, as far as higher rate of ascent is concerned, have been obtained with two-piece, streamlined balloons. These are made by attaching a streamlined tail made from balloon film to a spherical, thick-wall balloon. This assembly operation is time consuming and costly, and there are obvious advantages to the construction of a balloon having a streamlined contour in one piece.

Faster rates of ascent have been achieved by the use of balloons having a 2/1 length/diameter ratio. This shape is still far removed from the ideal streamlined shape and may become unstable at higher altitudes.

The major problem in making a one-piece, streamlined balloon is that a gel stripped from a dipping form of almost any shape will tend to become spherical on inflation unless parts of the balloon are restricted by the use of girdles.

It, therefore, becomes necessary to determine what shape the original dipping form should have in order to produce a streamlined balloon after inflation with a minimum of restriction during inflation.

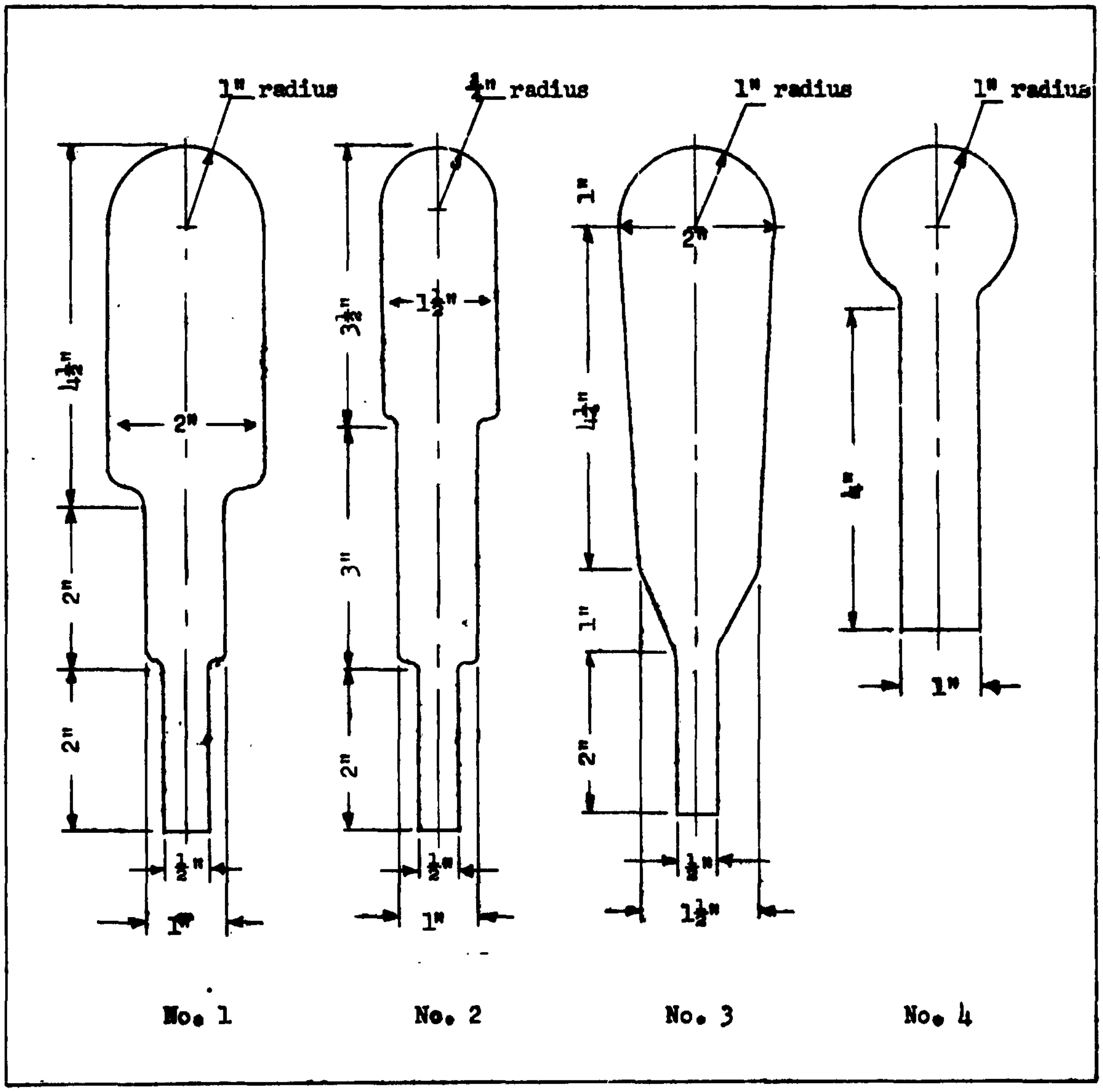
A group of four prototype dipping forms were constructed, the designs of which are illustrated in Figure 40.

All forms have a circular cross section at any point and are variously designed to provide for greater inflation of the top of the balloon, the top being the end opposite from the neck.

Initial tests indicate that Form No. 4 in Figure 40 gave the most promising results. However, the shape obtained with this form was still far from what was desired; and in view of the apparently great difficulties involved, this line of investigation was abandoned.

FIGURE 40

PROTOTYPE DIPPING FORMS FOR STREAMLINED BALLOONS



FACTUAL DATA (continued)

TASK C: (continued)

Phase 2: Construction of One Piece Balloons for Flight Testing

In Contract DA-36-039-SC-78239, some success was achieved with long, tubular balloons insofar as improved ascensional rate is concerned. A balloon with a length/diameter ratio of approximately 9/1 showed an average ascensional rate of 1516 feet per minute when flown with a free lift of 3000 grams. This equals the ascensional rate of a spherical balloon made from the same compound and flown with a free lift of 5000 grams.

Analysis of the flight showed that the average rate of ascent to 30,000 feet was 1724 feet per minute. Above this altitude there was a sharp decrease in rate of ascent, and the average for the remainder of the flight was only 1343 feet per minute. It may be concluded, therefore, that the balloon becomes unstable as the inflation increases.

Flights performed during contract DA-36-039-SC-78239 using 2/1 length/diameter ratio forms with standard compound showed little improvement in rate of ascent, but it was considered advisable to make similar balloons using a high-modulus compound.

Accordingly, balloons were dipped on the smallest of the 2/1 ratio forms which gives a balloon weighing about 600 grams. Three of these balloons were submitted for flight testing. They were flown in the daytime with a free lift of 1400 grams. This is the normal lift for a standard 600-gram balloon. The characteristics of these balloons and the flight results are given in Table 199.

A study of this table shows that the shape of the balloon has made a distinct contribution toward improving the rate of ascent. Spherical balloons of a similar weight and size flown previously showed rates of ascent at least 100 feet per minute less when flown with the same free lift.

Balloons were now made on the next size 2/1 ratio form which results in a balloon weighing approximately 1000 grams. These balloons were also made from compound A3-102, and three of them were submitted for flight testing. They were flown in the daytime with a free lift of 1600 grams, the standard free lift for a 1000-gram balloon. The characteristics of these balloons and the flight results are given in Table 200.

A study of the table shows that the rate of ascent has been maintained at approximately 1300 feet per minute. As is to be expected, the increased balloon weight and length has also resulted in the higher bursting altitudes.

FACTUAL DATA (continued)

TABLE 199

FLIGHT RESULTS - 2/1 RATIO BALLOONS MADE FROM COMPOUND A3-102

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Flaccid Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-2C-101	F28-1	Day	570	70	92,000	1311
EX-2C-102	F28-4	Day	563	72	90,300	1272
EX-2C-103	F29-1	Day	560	73	84,000	1294

TABLE 200

FLIGHT RESULTS - 2/1 RATIO BALLOONS MADE FROM COMPOUND A3-102

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Flaccid Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-2C-201	H3-4	Day	1000	96	97,300	1272
EX-2C-202	H4-1	Day	1010	90	99,400	1323
EX-2C-203	H4-2	Day	985	94	92,600	1330

TABLE 201

FLIGHT RESULTS - 2/1 RATIO BALLOONS MADE FROM COMPOUND A3-102

Experiment No.	Balloon No.	Day or Night Flight	Weight (grams)	Flaccid Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-2C-204	H20-2	Day	1000	87	92,600	1438
EX-2C-205	H20-3	Day	1050	90	70,800	1380
EX-2C-206	H24-2	Day	1050	83	83,600	1446
EX-2C-211	H24-3 H25-2	Day	1885	82	75,200	1484
EX-2C-212	H25-3 H26-1	Day	1900	84	82,500	1548

FACTUAL DATA (continued)

TASK C, Phase 2 (continued)

The next step was to determine the effect of increasing the free lift and increasing the wall thickness to provide greater stiffness. Five more balloons were therefore submitted for flight testing. These were identified as EX-2C-204 through EX-2C-206 and EX-2C-211 and EX-2C-212.

Balloons EX-2C-204 and EX-2C-206 weighed about 1000 grams and were flown in the daytime with a free lift of 2700 grams. Balloon EX-2C-205 also weighed 1000 grams and was flown in the daytime with a free lift of 3700 grams.

Balloons EX-2C-211 and EX-2C-212 were made by inserting one 1000-gram balloon inside another similar balloon. The assembly in each case weighed approximately 1900 grams and had, of course, twice the wall thickness of a single balloon. They were flown in the daytime with a free lift of 2700 grams.

The characteristics of these balloons and their flight performance are given in Table 201.

Analysis of these results shows that increasing the free lift to 2700 grams results in an increased rate of ascent, the average of these two flights being 1442 feet per minute. A further increase in free lift to 3700 grams failed to improve the rate of ascent, actually reducing it to 1380 feet per minute.

The two balloons with the increased wall thickness showed a further improvement in ascensional rate when flown with a free lift of 2700 grams, the average of the two flights being 1516 feet per minute.

Phase 3: Construction of Balloons having Mechanical Attachments to Improve Rate of Ascent

The rate of ascent achieved by thick-walled 2/1 ratio balloons suggests that if the shape were further streamlined by the addition of a tubular, conical tail, rates in the order of 1700 to 1800 feet per minute should be obtained. A composite balloon was therefore constructed as follows:

> 600-gram, 2/1-ratio balloons were used since they were immediately available. One balloon was inserted inside another similar balloon, the balloons chosen having the same deflated length. The interior balloon was inflated to drive out the air trapped between the two balloons, and the balloons were then cemented together at the neck.

FACTUAL DATA (continued)

TASK C, Phase 3 (continued)

The top of a third balloon was removed around a line at the end of the tubular section, and this opening was cemented to the end of the tubular section nearest the neck of the two balloon assembly. The completed assembly now had the appearance shown in Figure 41.

The twin balloon assembly was inflated to the desired lift, and the radiosonde was attached to this balloon neck as indicated. The open neck of the tail balloon was secured to the radiosonde line to keep it taut during flight, but the appendage was left open to prevent expansion of the tail balloon.

Two balloon assemblies of this type were prepared and flown with a free lift of 2700 grams. The characteristics of these balloons and their flight performance are given in Table 202.

Analysis of these results shows that no improvement in rate of ascent over that of the twin balloon without the tail has been obtained. In both flights the average rate of ascent has been reduced. However, it may also be observed that the initial rate of ascent is greater than that of the latter part of the flight. This is particularly true in the case of balloon assembly EX-2C-1001.

It would appear, therefore, that the tail is effective only in the early stages of the flight and becomes a drag in the latter part of the flight. This is probably because the tail was too short and was located too low on the carrier balloon.

An additional four balloons of the 2/1 length/diameter ratio were now prepared with tubular tails attached at a circumference approximately half way along the length. Two of these tails were approximately twice the length of the original balloon and two were approximately three times the length. The tubular tails were in all cases of the same diameter as that of the original balloon. The four balloons, which were identified as EX-2C-1003 through EX-2C-1006 were flown during the day with a free lift of 2700 grams. The characteristics of these balloons and their flight performance are given in Table 203.

FIGURE 41

2/1 RATIO STREAMLINED BALLOON ASSEMBLY

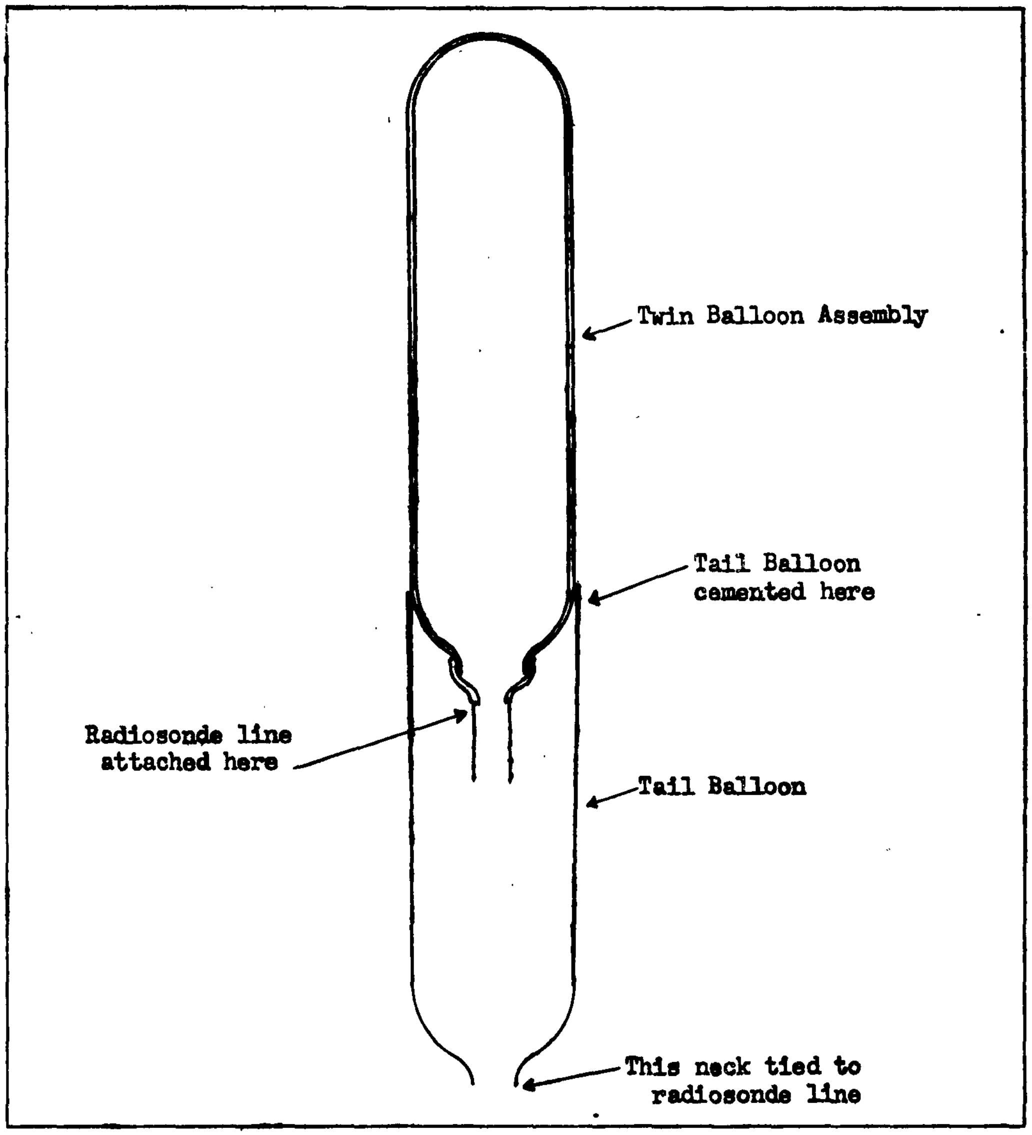


TABLE 202

FLIGHT RESULTS - 2/1 RATIO BALLOONS WITH TAIL SECTION

Experimental No.	EX-2C-1001	EX-2C-1002
Balloon Assembly	F27-3, F29-2	F29-4, F29-3
Tail Balloon	F27-5	F27-2
Total Weight (grams)	1430	1375
Balloon Length (inches)	68	74
Assembly Length (inches)	127	131
Day or Night Flight	Day	Day
Free Lift (grams)	2,700	2,700
Altitude at Burst (feet)	62,000	65,100
Avg. Rate of Ascent (feet/min)	1,480	1,394
Rate of Ascent:		
0 - 10,000 feet	1,538	1,515
10,000 - 20,000 feet	1,667	1,408
20,000 - 30,000 feet	1,563	1,316
30,000 - 40,000 feet	1,493	1,408
40,000 - 50,000 feet	1,299	1,370
50,000 - burst	1,389	1,389

FACTUAL DATA (continued)

TASK C, Phase 3 (continued)

A study of this table shows that very little improvement in rate of ascent has been achieved by any of the measure adopted. The two balloons with the double tail section ascended slightly faster than the two flown previously with a single tail. However, those with the three balloon tails were slower than either of the others. It would appear that this design is incapable of reaching an ascensional rate of much more than 1500 feet per minute.

In addition, to the above balloons, two spherical balloons with a tail section were also manufactured and flown. The balloons proper were 1100 grams with a wall thickness of approximately .007 inch compared with the standard wall thickness of approximately .003 inch. These balloons, consequently, had flaccid lengths of about 70 inches.

To these, a thin-walled, 800-gram balloon was attached at a circumference approximately one foot below the equator of the balloon. The upper portion of the 800-gram balloon was cut away so that at the circle of attachment the 800-gram balloon was under no extension when the balloon proper was inflated to its flaccid diameter.

These two balloons, which were identified as EX-2C-1101 and EX-2C-1102, were both flown during the daytime with a total lift of 5950 grams, which is equivalent to a free lift of approximately 2700 grams. The characteristics of these balloons and their flight performance are given in Table 204.

It is immediately apparent that this assembly is superior to the 2/1 ratio assemblies. Both balloons achieved excellent rates of ascent and the altitude reached by EX-2C-1102 is very satisfactory for a balloon of this size.

In view of the above, it was considered possible that the tubular tail attached half way along the balloon proper was restricting the inflation of the lower half of the balloon and preventing the development of a good streamlined shape.

Therefore, a group of tubular balloons was prepared to which a tail cut from a spherical balloon and similar to that employed on the ML-541 balloon was attached. The tail balloon was made from a low-modulus compound and should provide a minimum of restriction on the expansion of the carrier balloon. At the same time it should maintain a conical, streamlined tail section for for the majority, if not all, of the flight.

Eight such balloons were fabricated, and they are identified as EX-2C-1011 through EX-2C-1018. They were all flown during the day with a free lift of 2700 grams. The characteristics of these balloons and their flight performance are given in Table 205.

TABLE 203

FLIGHT RESULTS - 2/1 RATIO BALLOONS WITH TAIL SECTION

Experiment No.	Carrier Balloon No.	Tail Balloon Nos.	Total Weight (grams)	Balloon Length (inches)	Assembly Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-2C-1003	R4-4	(R17-3 (R17-5	1675	63	149	58,500	1525
EX-2C-1004	R9-4	(R17-6 (R18-2	1645	66	135	61,200	1561
EX-2C-1005	R12-3	(R18-4 (R18-5 (R19-2	1885	62	193	53,400	1420
EX-2C-1006	R12-4	(R19-4 (R22-1 (R22-2	1905	60	207	49,500	1352

TABLE 204

FLIGHT RESULTS - SPHERICAL BALLOONS WITH TAIL SECTIONS

Experiment No.	Carrier Balloon No.	Tail Balloon Type	Total Weight (grams)	Balloon Length (inches)	Assembly Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-2C-1101	R15-4	800 gm. (prod.)	1970	73	132	44,200	2167
EX-2C-1102	R16-3	800 gm. (prod.)	1890	71	132	87,900	1923

TABLE 205

FLIGHT RESULTS - 2/1 RATIO BALLOONS WITH TAIL SECTION

Experiment No.	Balloon No.	Total Weight (grams)	Balloon Length (inches)	Assembly Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-2C-1011	K27-3	1305	69	116	pinhole tied off - burst	
EX-2C-1012	M28-6	1370	63	121	53,100	1455
EX-2C-1013	R10-3	1480	57	116	44,700	1221
EX-2C-1014	R11-4	1485	58	115	37,000	1121
EX-2C-1015	S23-3	1380	58	120	41,900	1174
EX-2C-1016	S23-4	1325	54	110	38,000	1166
EX-2C-1017	S23-6	1380	54	110	40,000	1143
EX-2C-1018	S26-7	1365	56	110	43,700	1191

FACTUAL DATA (continued)

TASK C, Phase 3 (continued)

Analysis of these results shows that this latest effort to improve the rate of ascent of the 2/1 length/diameter ratio balloons has actually had the reverse of the desired effect.

Of all the flights made with 2/1 length/diameter ratio balloons, these are the slowest; and there seems to be no purpose in pursuing this line of investigation further.

A further six spherical streamlined balloons were also submitted for flight testing which were of the same type as the two balloons previously submitted.

Three of these balloons consisted of a balloon proper weighing about 1100 grams and having a flaccid length of 70 inches and a wall thickness of about 0.007 inch. A thin-walled ML-518 balloon was attached at a circumference approximately one foot below the equator of the balloon as already described. These balloons are identified as EX-2C-1103, EX-2C-1104 and EX-2C-1105. They were flown during the day with a total lift of 5950 grams.

The remaining three balloons were post-plasticized for flight at night. As a consequence, the weight of the balloon proper increased to about 1200 grams and the length to 74 inches. A post-plasticized tail was attached in the same manner as to the day-flight balloons. These balloons are identified as EX-2C-1111, EX-2C-1112, and EX-2C-1113. They were flown with a free lift of 2700 grams.

The characteristics of these six balloons and their flight performance are given in Table 206.

Analysis of these results shows that although the balloons reached satisfactory altitudes in most cases by both day and night, the rates of ascent are considerably below those obtained previously. However, the rate of ascent by both day and night is the same, the average day-flight rate being 1525 feet per minute, and the average night-flight being 1515 feet per minute.

A further series of flights was conducted with ten balloons of the same type as those previously flown in an effort to duplicate the original results.

These consisted of a thick-walled, high-modulus balloon approximately 70 inches in length to which was attached a tail section which increased the over-all length of the balloon to about 115 inches in the case of the day-flight balloons and to 125 inches in the case of the night-flight balloons. This tail section was cemented to a circle approximately six inches below the equator of the 70-inch balloon.

FACTUAL DATA (continued)

TASK C, Phase 3 (continued)

The balloons were identified as EX-2C-1121 through EX-2C-1130. Balloons EX-2C-1121 through EX-2C-1125 were flown in the daytime, and balloons EX-2C-1126 through EX-2C-1130 were flown at night. All balloons were flown with a free lift of 2700 grams. The characteristics of these balloons and their flight performance are given in Table 207.

A study of these results shows excellent consistency insofar as ascensional rate is concerned. The rate of ascent, nevertheless, is substantially below the 1800 feet per minute which is the objective. Both the day-flight and the night-flight balloons rise at about the same rate, the night-flight balloons being slightly slower.

Similarly, the altitude reached by both the day-flight and the night-flight balloons is substantially the same; and although fairly satisfactory for a balloon of this size, it is lower than the altitude reached by comparable balloons flown in the past.

Mr. Sharenow noted that during inflation the tail balloon was drawn up around the lower part of the carrier balloon so that at release there remained only about one to two feet of tail hanging below the spherical balloon. As the balloon expanded, this must have rapidly disappeared, and during the greater part of the flight the balloon must have been virtually spherical. Under these conditions the performance of the balloon must be considered as remarkably good.

It is suggested that a carrier balloon 90 inches in length with a longer tail or with the tail cemented at a lower circle on the balloon should be capable of reaching 80,000 feet at at least 1800 feet per minute and that proportionate increases in the size of the assembly should provide a balloon capable of reaching 100,000 feet at the same ascensional rate.

Accordingly, four more balloons of the same type were submitted for flight testing, and the following changes were made in their construction. Instead of using the high-modulus compound A3-102 for the carrier balloon, compound A3-104 was used. This latter compound is a true dual-purpose compound so that post-plasticizing for night flight which is necessary in the case of compound A3-102 would not be required. Compound A3-104 has a somewhat lower modulus than A3-102, but it was felt that the modulus of A3-104 would still be satisfactory in a thick-walled balloon.

The length of the carrier balloon was increased to 105 inches for two of the balloons and to 115 inches for the remaining pair; and the weights of the carriers were raised from approximately 1000 grams to 2000 grams.

FACTUAL DATA (continued)

TABLE 206

FLIGHT RESULTS - SPHERICAL BALLOONS WITH TAIL SECTION

Experiment No.	Balloon No.	Day or Night Flight	Total Weight (grams)	Balloon Length (inches)	Assembly Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-2C-1103	S20-3	Day	1900	70	119	79,200	1600
EX-2C-1104	S27-3	Day	1850	71	125	79,000	1530
EX-2C-1105	S28-3	Day	1865	70	126	73,000	1448
EX-2C-1111	R16-4	Night	2250	74	121	76,900	1709
EX-2C-1112	R17-2	Night	2415	74	121	68,900	1472
EX-2C-1113	R17-4	Night	2405	73	129	80,000	1363

TABLE 207

FLIGHT RESULTS - SPHERICAL BALLOONS WITH TAIL SECTION

Experiment No.	Carrier Balloon No.	Tail Balloon Type	Total Weight (grams)	Balloon Length (inches)	Assembly Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-2C-1121	A5-3	800 gm	1715	70	114	62,500	1560
EX-2C-1122	A5-4	800 gm	1670	70	113	70,300	1666
EX-2C-1123	A6-2	800 gm	1710	71	112	62,000	1619
EX-2C-1124	A6-3	800 gm	1685	71	112	47,800	1593
EX-2C-1125	A9-1	800 gm	1690	70	112	69,500	1650
EX-2C-1126	A5-1	1000 gm	2035	75	126	63,000	1544
EX-2C-1127	A5-2	1000 gm	2205	74	132	60,900	1530
EX-2C-1128	A6-1	1000 gm	2145	72	136	56,100	1558
EX-2C-1129	A6-4	1000 gm	2150	73	127	57,300	1524
EX-2C-1130	A9-2	1000 gm	2060	73	127	64,000	1580

FACTUAL DATA (continued)

TASK C, Phase 3 (continued)

The length of the streamlined tail was increased from approximately 50 inches to 90 inches, and the tail was affixed to the carrier balloon on a circle 18 inches below the maximum diameter, resulting in a total assembly length of about 200 inches as compared with a maximum of 130 inches for the previous group of balloons.

Characteristics of these balloons and their flight results are recorded in Table 208.

Balloons EX-2C-1141, EX-2C-1143, and EX-2C-1144 were flown with a free lift of 3700 grams.

Balloon EX-2C-1142 was flown with a free lift of 4200 grams.

All balloons were flown in the daytime.

TABLE 208

FLIGHT RESULTS - SPHERICAL BALLOONS WITH TAIL SECTIONS

Experiment No.	Carrier Balloon No.	Tail Balloon Type	Total Weight (grams)	Balloon Length (inches)	Assembly Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-2C-1141	F21-2AM	1500 gm	2895	106	198	74,300	1591
EX-2C-1142	F24-2AM	1500 gm	2760	103	197	91,090	1491
EX-2C-1143	F26-3AM	1500 gm	2950	116	200	95,900	1345
EX-2C-1144	F27-2AM	1500 gm	2835	114	198	83,300	1469

FACTUAL DATA (continued)

TASK C, Phase 3 (continued)

A study of these results shows that a substantial improvement in altitude has been obtained, two of the balloons reaching altitudes of over 90,000 feet. However, no improvement in the rate of ascent is apparent, and of the four flights only one ascended at a rate comparable to those of the previous group.

Again, Mr. Sharenow of USAERDL reported that, upon inflation, the upper part of the balloon above the circle on which the tail section was attached bulged, creating the appearance that the tail was attached much more than 18 inches below the major diameter. The streamlined shape was therefore destroyed, and it seems probable that this undesirable shape was retained through the greater part of the flight.

Thus it is evident that compound A3-104 does not have a sufficiently high modulus for this type of balloon.

The physical properties of compound A3-134 suggest that it should be suitable for use in fast-rising balloons. Accordingly, thick-walled balloons were manufactured from this compound.

At the same time, three thick-walled balloons were also manufactured from compound A3-102. This is a sulphur-bearing compound, and experience has shown that the life of this compound in a dipping tank is limited, a condition similar to that of pre-cure in a natural latex compound developing upon storage for two or three months.

It would seem that cross-linking occurs in the latex phase due to the presence of the sulphur; and if good performance can be obtained with balloons made from compound A3-134, this problem would be eliminated.

On all of these balloons a tail, consisting of approximately four-fifths of a thin-walled, 1000-gram balloon made from compound A3-106, was affixed at a circle approximately 18 inches below the equator of the thick-walled balloon.

FACTUAL DATA (continued)

TASK C, Phase 3 (continued)

The balloons made from compound A3-102 were identified as EX-2C-1151 through EX-2C-1153. The balloons made from compound A3-134 were identified as EX-2C-1161 through EX-2C-1167 and EX-2C-1171 through EX-2C-1176. Seven of these balloons were post-plasticized, six of which were flown at night and one during the day. The post-plasticized balloons are EX-2C-1165 through EX-2C-1167, EX-2C-1171, EX-2C-1172, EX-2C-1174 and EX-2C-1176.

All of these balloons were flown with a free lift of 2700 grams. Their characteristics and flight performance are given in Table 209.

In order to evaluate the performance of these balloons more realistically, the rate of ascent over 10,000-foot intervals was calculated as well as the temperature at each 10,000-foot level. The results of these calculations are given in Tables 210 through 212.

These calculations were performed only for balloons EX-2C-1151 through EX-2C-1153 and EX-2C-1161 through EX-2C-1167, but may be considered to be representative.

An examination of these flight data shows that in every case the balloon accelerates until about the middle altitude attained and then gradually decelerates for the remainder of the flight. Balloons EX-2C-1151 and EX-2C-1152 show curiously large accelerations in the last stages of the flight, but it is felt that these figures should be regarded with suspicion. This behavior is usual for this type of balloon and, in part, is certainly due to the fact that as the balloon expands the tail is drawn up around the lower part of the balloon thus destroying the streamlined shape. This will tend to reduce the rate of ascent of the balloon, but it is more than offset during the latter part of the flight by the reduction in atmospheric density and, therefore, the viscosity.

A closer examination of the flights of balloons EX-2C-1151, EX-2C-1152, and EX-2C-1153, however, reveals another point. Balloon EX-2C-1151 was the lightest and longest balloon and, therefore, had the lowest wall thickness. Nevertheless, it achieved the highest rate of ascent, and furthermore, the minimum temperature encountered was the highest of the three flights. Balloon EX-2C-1153 had the greatest wall thickness, encountered the lowest temperature, and was the slowest of the three balloons.

FACTUAL DATA (continued)

TASK C, Phase 3 (continued)

TABLE 209

FLIGHT RESULTS - STREAMLINED BALLOONS MADE FROM COMPOUNDS A3-102 AND A3-134

Experiment No.	Balloon No.	D or N	Balloon Weight (grams)	Balloon Length (inches)	Assembly Weight (grams)	Assembly Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
				Compound A3-102				
EX-2C-1151	M18-1AM	D	1765	111	2700	158	94,600	1736
EX-2C-1152	M18-2AM	D	2290	106	3205	155	102,600	1667
EX-2C-1153	M18-3AM	D	2410	106	3405	159	97,960	1523
				Compound A3-134				
EX-2C-1161	S14-3AM	D	1815	105	2820	156	94,000	1646
EX-2C-1162	S14-4AM	D	2145	103	3220	159	80,500	1779
EX-2C-1163	S14-5AM	D	2085	94	3065	147	91,300	1718
EX-2C-1164	S14-6AM	D	2070	97	3070	156	92,400	1406
EX-2C-1165	S14-7AM	N	2320	115	3320	159	90,960	1448
EX-2C-1166	S15-5AM	N	2425	99	3390	149	68,100	1357
EX-2C-1167	S15-6AM	N	2340	103	3200	147	83,000	1584
EX-2C-1171	T2-3TK	N	1850	98	2845	156	85,900	1576
EX-2C-1172	T3-2TK	N	1780	101	2790	155	88,400	1506
EX-2C-1173	T3-4TK	D	1515	89	2470	152	89,590	1566
EX-2C-1174	T3-5TK	D	1825	87	2830	150	77,140	1819
EX-2C-1175	T4-2TK	D	1580	89	2710	157	88,100	1653
EX-2C-1176	T4-3TK	N	1915	99	2850	150	93,400	1578

FACTUAL DATA (continued)

TASK C, Phase 3 (continued)

TABLE 210

FLIGHT ANALYSIS - BALLOONS EX-2C-1151 THROUGH EX-2C-1153

Altitude Interval (feet)	EX-2C-1151		EX-2C-1152		EX-2C-1153	
	Temp. (°C)	Ascent (ft/min)	Temp. (°C)	Ascent (ft/min)	Temp. (°C)	Ascent (ft/min)
0 - 10,000	29.0	1358	29.0	1467	30.0	1608
10,000 - 20,000	10.0	1736	6.0	1704	7.5	1694
20,000 - 30,000	- 4.5	1825	-10.5	1952	- 7.5	2012
30,000 - 40,000	-28.0	2000	-33.5	2024	-27.5	1821
40,000 - 50,000	-55.0	2486	-58.5	1594	-52.5	1542
50,000 - 60,000	-66.0	1982	-68.0	1755	-73.0	2191
60,000 - 70,000	-58.5	2000	-	2052	-63.5	1120
70,000 - 80,000	-54.0	1727	-	1116	-54.5	1218
80,000 - 90,000	-44.5	1317	-	1072	-48.5	1571
90,000 - 100,000	-42.5	2294	-48.5	3155 ?	-42.0	1106
Temp. at Burst	-38.5		-41.5		-41.0	
Average Rate of Ascent		1736		1667		1523

FACTUAL DATA (continued)

TASK C, Phase 3 (continued)

TABLE 211

FLIGHT ANALYSIS - BALLOONS EX-2C-1161 THROUGH EX-2C-1164

Altitude Interval (feet)	EX-2C-1161		EX-2C-1162		EX-2C-1163		EX-2C-1164	
	Temp. (°C)	Ascent (ft/min)	Temp. (°C)	Ascent (ft/min)	Temp. (°C)	Ascent (ft/min)	Temp. (°C)	Ascent (ft/min)
0- 10,000	26.5	1400	29.0	1430	24.0	1308	25.5	1177
10,000- 20,000	8.5	1559	6.5	1807	3.0	2312	6.5	1285
20,000- 30,000	- 7.0	1781	- 8.5	2089	- 9.0	2125	- 8.5	1397
30,000- 40,000	-30.5	2047	-34.0	2382	-32.0	1833	-30.5	1426
40,000- 50,000	-49.0	2212	-52.0	2315	-50.0	1553	-56.5	1561
50,000- 60,000	-67.5	1814	-63.5	1793	-56.5	1789	-68.0	1645
60,000- 70,000	-64.0	1711	-65.0	1677	-65.5	1854	-60.5	1677
70,000- 80,000	-59.0	1636	-58.0	1324	-59.5	1672	-56.5	1469
80,000- 90,000	-49.0	1216	-49.5	-	-49.5	1520	-48.5	1196
90,000-100,000	-42.0	1320						
Temp. at Burst	-43.6		-49.5		-45.0		-43.0	
Average Rate of Ascent		1646		1779		1718		1406

FACTUAL DATA (continued)

TASK C, Phase 3 (continued)

TABLE 212

FLIGHT ANALYSIS - BALLOONS EX-2C-1165 THROUGH EX-2C-1167

Altitude Interval (feet)	EX-2C-1165		EX-2C-1166		EX-2C-1167	
	Temp. (°C)	Ascent (ft/min)	Temp. (°C)	Ascent (ft/min)	Temp. (°C)	Ascent (ft/min)
0 - 10,000	27.0	1446	28.0	1202	28.5	1494
10,000 - 20,000	5.5	1272	5.5	1406	9.0	1743
20,000 - 30,000	-14.0	1486	-10.5	1414	- 8.0	1829
30,000 - 40,000	-38.0	2362	-31.5	1539	-28.5	1828
40,000 - 50,000	-55.5	2291	-56.5	1500	-54.0	1782
50,000 - 60,000	-65.0	1701	-72.0	1380	-66.5	1508
60,000 - 70,000	-59.5	1210	-62.0	1137	-64.0	1522
70,000 - 80,000	-54.5	1247			-56.0	1244
80,000 - 90,000	-52.0	987			-50.0	1296
Temp. at Burst	-46.5		-57.0		-51.0	
Average Rate of Ascent		1448		1357		1584

TASK C, Phase 3 (continued)

Of the four balloons, EX-2C-1161 through EX-2C-1164, the latter encountered the lowest temperature and was the slowest balloon. It also had a relatively high wall thickness. Balloons EX-2C-1161 and EX-2C-1162 had lower wall thicknesses than either of the other two and were both faster than EX-2C-1164.

The minimum temperatures encountered by EX-2C-1161 and EX-2C-1162 were also higher than that encountered by EX-2C-1164. Balloon EX-2C-1163 encountered about the same minimum temperature as did EX-2C-1162 but had a greater wall thickness and was somewhat slower.

The internal pressure developed in a balloon depends on the modulus of the film and the wall thickness. For a given compound, the modulus increases as the temperature decreases. Now, an increase in internal pressure will have the effect of increasing the density of the lifting gas, thereby reducing the total lift. The fact that all the night flights were slower than the day flights (the exception being EX-2C-1164) and that the balloon is much colder and therefore liable to have a much higher modulus, even though post-plasticized, suggest that compounds A3-102 and A3-134 have too high a modulus.

The rate of ascent attained with balloon EX-2C-1174 which was post-plasticized and flown in the daytime and which gave the highest rate of ascent of any of the last group of flights tends to confirm this.

The altitudes attained by these balloons agree rather well with the forecast of the theoretical study presented in Task B, Phase 6, of this report.

An additional five balloons of this type were manufactured from a compound designated A3-137 which was identical to A3-134 except that the plasticizer content was increased to render the balloons capable of flight by night. The balloons were fitted with a tail section made from compound A3-106. The carrier balloons were approximately 100 inches long and the assemblies weighed approximately 3000 grams.

The balloons were identified as EX-2C-1181 through EX-2C-1185 and were flown with a free lift of 2700 grams. Their characteristics and flight performance are recorded in Table 213.

Balloons of this size, according to theoretical calculations (see Task B, Phase 6) should be capable of reaching altitudes of approximately 80,000 to 85,000 feet. A study of the table shows that the anticipated altitudes have been reached, and the rate of ascent of three of the balloons is substantially in excess of 1700 feet per minute.

FACTUAL DATA (continued)

TASK C, Phase 3 (continued)

TABLE 213

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-137

Experiment No.	Balloon No.	D or N	Balloon Weight (grams)	Balloon Length (inches)	Assembly Weight (grams)	Assembly Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-2C-1181	T3-3AM	N	1920	99	2960	151	92,500	1762
EX-2C-1182	T3-4AM	N	1980	98	2950	152	84,600	1796
EX-2C-1183	T4-1AM	D	1910	99	2935	153	90,200	1686
EX-2C-1184	T4-2AM	N	2000	98	3070	153	88,600	1579
EX-2C-1185	T4-5AM	D	1875	92	2870	149	86,300	1848

FACTUAL DATA (continued)

TASK C, Phase 3 (continued)

A fourth balloon failed to achieve this rate of ascent by only 14 feet per minute; but the fifth balloon was significantly slower averaging only 1579 feet per minute.

In order to evaluate these flights in greater detail, the rate of ascent was calculated over 10,000 foot intervals from release to burst. The temperature at these same intervals was also determined, and the results of these five flights analyzed in the above manner are recorded in Tables 214 and 215.

It was observed in every case that the rate of ascent reaches a maximum at between 30,000 and 60,000 feet, and above these altitudes there is a more or less sharp deceleration. The rate of ascent to 80,000 feet was calculated since this is the altitude to which the balloon is designed to rise and it is to this altitude that the rate of ascent can be most logically measured.

It is obvious that in every case except that of EX-2C-1183 the rate of ascent has now been increased and that three of the flights have an average ascensional rate of 1800 feet per minute, with the fourth still, however, at a rate less than 1700 feet per minute. The rate of ascent of EX-2C-1183 is virtually unchanged. These balloons may be considered to be meeting their theoretical potential with fairly good consistency.

An additional group consisting of six balloons with increased weight and length were submitted for flight testing. These balloons were made from compound A3-137 and fitted with tails made from compound A3-106. They were identified as EX-2C-1191 through EX-2C-1196 and were flown with a free lift of 2700 grams. Their characteristics and flight performance are given in Table 216.

A study of this table shows that the flights obtained are generally disappointing. There has been little increase in the altitude despite the increase in length of the carrying balloon, and the rates of ascent are substantially slower than those previously attained with the smaller balloons. An analysis of four of these flights was, therefore, made and the results of this analysis are given in Table 217.

This table shows that there is a distinctly different pattern in ascensional rate over 10,000-foot intervals than was shown by balloons EX-2C-1181 through EX-2C-1185.

FACTUAL DATA (continued)

TASK C, Phase 3 (continued)

TABLE 214

FLIGHT ANALYSIS - BALLOONS EX-2C-1181 THROUGH EX-2C-1183

Altitude Interval (feet)	EX-2C-1181		EX-2C-1182		EX-2C-1183	
	Temp. (°C)	Ascent (ft/min)	Temp. (°C)	Ascent (ft/min)	Temp. (°C)	Ascent (ft/min)
0 - 10,000	10.0	1348	9.0	1405	17.1	1097
10,000 - 20,000	4.8	1650	1.1	1583	3.0	1084
20,000 - 30,000	-21.8	1914	-21.6	1888	-19.0	2340
30,000 - 40,000	-41.1	2226	-42.6	2290	-36.7	1841
40,000 - 50,000	-56.8	2702	-57.5	2288	-58.3	2272
50,000 - 60,000	-62.8	1903	-62.8	2130	-70.2	2090
60,000 - 70,000	-61.3	1765	-62.0	1611	-62.0	1938
70,000 - 80,000	-61.4	1716	-61.2	1634	-61.4	1824
80,000 - 90,000	-58.0	1416	-59.2	1741	*	1724
Temp. at Burst	-52.0		-58.0		*	
Average Rate of Ascent		1762		1796		1686
Average Rate of Ascent to 80,000 feet		1827		1800		1680

* information not available

FACTUAL DATA (continued)

TASK C, Phase 3 (continued)

TABLE 215

FLIGHT ANALYSIS - BALLOONS EX-2C-1184 AND EX-2C-1185

Altitude Interval (feet)	EX-2C-1184		EX-2C-1185	
	Temp. (°C)	Ascent (ft/min)	Temp. (°C)	Ascent (ft/min)
0 - 10,000	11.0	1283	12.0	1504
10,000 - 20,000	4.5	1557	- 0.2	1744
20,000 - 30,000	-20.8	1623	-18.5	1936
30,000 - 40,000	-40.2	2447	-40.3	2141
40,000 - 50,000	-54.8	1561	-56.3	2186
50,000 - 60,000	-63.2	2195	-62.7	2222
60,000 - 70,000	-63.0	1478	-61.5	1839
70,000 - 80,000	-60.8	1262	-60.4	1681
80,000 - 90,000	-58.3	1333	-59.3	1580
Temp. at Burst	-56.7		-56.0	
Average Rate of Ascent		1579		1848
Average Rate of Ascent to 80,000 feet		1600		1867

FACTUAL DATA (continued)

TASK C, Phase 3 (continued)

TABLE 216

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-137

Experiment No.	Balloon No.	D or N	Balloon Weight (grams)	Balloon Length (inches)	Assembly Weight (grams)	Assembly Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-2C-1191	W7-3	D	3275	135	4915	192	88,100	1454
EX-2C-1192	W9-1	N	3290	131	4810	183	95,700	1348
EX-2C-1193	W9-2	N	3430	131	4890	190	96,100	1363
EX-2C-1194	W9-3	D	3240	129	4865	188	88,000	1234
EX-2C-1195	W10-3	N	3345	123	5120	189	79,000	952
EX-2C-1196	W10-4	D	3290	123	4850	193	88,800	1425

FACTUAL DATA (continued)

TASK C, Phase 3 (continued)

TABLE 217

FLIGHT ANALYSIS - BALLOONS EX-2C-1192, EX-2C-1193, EX-2C-1195, AND EX-2C-1196

Altitude Interval (feet)	EX-2C-1192		EX-2C-1193		EX-2C-1195		EX-2C-1196	
	Temp. (°C)	Ascent (ft/min)	Temp. (°C)	Ascent (ft/min)	Temp. (°C)	Ascent (ft/min)	Temp. (°C)	Ascent (ft/min)
0- 10,000	1.7	1047	3.0	1096	2.9	911	- 0.6	1106
10,000- 20,000	- 7.8	1248	-17.3	1314	- 8.0	935	- 7.5	1119
20,000- 30,000	-28.0	1280	-30.8	1327	-28.5	838	-25.2	1247
30,000- 40,000	-46.3	1552	-43.0	1547	-47.0	1000	-46.2	1392
40,000- 50,000	-54.3	1563	-51.8	1645	-55.0	990	-55.5	1412
50,000- 60,000	-57.8	1508	-51.7	1615	-58.7	1122	-56.6	1587
60,000- 70,000	-55.7	1565	-52.3	1306	-58.4	939	-54.6	1714
70,000- 80,000	-58.9	1579	-59.6	1337	-58.6	910	-56.6	2022
80,000- 90,000	-57.8	1311	-58.8	1089			-57.7	1796
90,000-100,000	-53.8	1000	-55.6	1958				
Temp. at Burst	-49.8		-54.0		-58.6		-53.7	
Average Rate of Ascent		1348		1363		952		1425

FACTUAL DATA (continued)

TASK C, Phase 3 (continued)

Balloons EX-2C-1192 and EX-2C-1193 show an almost constant rate of ascent from 30,000 to 80,000 feet. Balloon EX-2C-1196 accelerated slowly to an altitude of 80,000 feet, and balloon EX-2C-1195 ascended fairly consistently at a rate less than 1000 feet per minute throughout the flight. These results are so erratic and in such sharp contradiction to those obtained with the EX-2C-1181 series that it was not possible to draw any conclusions from them.

In order to further determine the effect of tension in the balloon film upon the rate of ascent, another series of streamlined balloons was prepared. In all cases, the carrier balloon was manufactured from compound A3-134. In order to provide variations in modulus, these balloons were individually post-plasticized to varying degrees, and two of them were not post-plasticized at all. In addition, these balloons were fitted with a double tail assembly.

It is possible to demonstrate that as the carrier balloon expands, the tail is gradually drawn up around the balloon and that the effective length of the tail becomes less and less throughout the flight until a point is reached where the tail virtually ceases to exist and the balloon becomes nominally spherical.

For balloons of the size in question flown under the conditions of lift being used, the tail will disappear at about 50,000 feet. It was felt that by attaching a second tail to a point approximately half way down the first tail, the streamlined shape could be preserved for a much greater part of the flight.

Eight balloons incorporating the double tail and the variations in modulus described above were submitted for flight testing. These balloons were identified as EX-2C-1201 through EX-2C-1208 and were flown with a free lift of 2700 grams. Characteristics of these balloons and their flight performance are given in Table 218.

A study of this table shows that the altitude reached and the rate of ascent are generally unsatisfactory. The loss in altitude is explained by the increased weight of the assembly resulting from the additional tail section. Also, the low altitudes of balloons EX-2C-1205 and EX-2C-1206 are probably accountable to the extremely low temperatures encountered on the night they were both flown.

The analysis of these flights is recorded in Tables 219 and 220.

FACTUAL DATA (continued)

TASK C, Phase 3 (continued)

TABLE 218

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-134 AND HAVING TWIN TAIL ASSEMBLIES

Experiment No.	Balloon No.	Day or Night Flight	Post-Plasticizer (% pickup)	Balloon Weight (grams)	Balloon Length (inches)	No. 1 Tail Weight (grams)	No. 1 Tail Length (inches)
EX-2C-1201	W10-2AM	Day	18.6	3275	124	985	106
EX-2C-1202	W29-1AM	Day	23.9	3280	129	955	101
EX-2C-1203	W29-3AM	Night	18.8	3320	129	975	101
EX-2C-1204	W29-4AM	Day	none	2810	114	910	98
EX-2C-1205	W30-1AM	Night	23.9	3290	128	955	104
EX-2C-1206	W30-2AM	Night	18.6	3255	128	930	101
EX-2C-1207	Y1-4AM	Day	10.0	2900	115	930	101
EX-2C-1208	Y5-2AM	Day	none	2665	114	935	100

TABLE 218 (continued)

Experiment No.	Balloon No.	No. 2 Tail Weight (grams)	No. 2 Tail Length (inches)	Assembly Weight (grams)	Assembly Length (inches)	Altitude at Burst (feet)	Rate of Ascent (ft/min)
EX-2C-1201	W10-2AM	690	62	5205	244	83,800	1486
EX-2C-1202	W29-1AM	720	63	5230	248	90,000	1676
EX-2C-1203	W29-3AM	690	62	5175	244	63,300	1576
EX-2C-1204	W29-4AM	750	60	4680	238	90,000	1424
EX-2C-1205	W30-1AM	730	61	5225	249	58,000	1629
EX-2C-1206	W30-2AM	635	57	5000	239	50,300	1421
EX-2C-1207	Y1-4AM	775	66	4775	244	78,300	1529
EX-2C-1208	Y5-2AM	825	68	4560	244	85,400	1743

TABLE 219

FLIGHT ANALYSIS - BALLOONS EX-2C-1201 THROUGH EX-2C-1204

Altitude Interval (feet)	EX-2C-1201		EX-2C-1202		EX-2C-1203		EX-2C-1204	
	Temp. (°C)	Ascent (ft/min)	Temp. (°C)	Ascent (ft/min)	Temp. (°C)	Ascent (ft/min)	Temp. (°C)	Ascent (ft/min)
0 - 10,000		1100		1260		1175		1180
10,000 - 20,000	-42.5	1300	-38.5	1570	-37.0	1485	-32.5	1390
20,000 - 30,000	-57.0	1360	-50.0	1790	-51.2	1615	-45.8	1575
30,000 - 40,000	-70.2	1630	-64.0	1875	-66.7	1730	-63.6	1730
40,000 - 50,000	-73.5	1790	-69.0	1900	-73.0	1750	-68.7	1870
50,000 - 60,000	-77.0	2060	-73.5	2350	-76.5	2065	-75.6	1600
60,000 - 70,000	-78.5	1700	-77.8	1840	-80.3	1409	-77.6	1110
70,000 - 80,000	-77.8	1530	-77.8	1640			-73.8	1290
80,000 - 90,000	-77.0	1180	-70.5	1330			-73.0	1400
Temp. at Burst	-73.0		-62.6		-79.0		-62.8	
Average Rate of Ascent		1486		1676		1576		1424

FACTUAL DATA (continued)

TASK C. Phase 3 (continued)

TABLE 220

FLIGHT ANALYSIS - BALLOONS EX-2C-1205 THROUGH EX-2C-1208

Altitude Interval (feet)	EX-2C-1205		EX-2C-1206		EX-2C-1207		EX-2C-1208	
	Temp. (°C)	Ascent (ft/min)	Temp. (°C)	Ascent (ft/min)	Temp. (°C)	Ascent (ft/min)	Temp. (°C)	Ascent (ft/min)
0 - 10,000	.	1140	.	1110		1095		1270
10,000 - 20,000	-34.5	1490	-31.3	1230	-36.8	1230	-40.6	1960
20,000 - 30,000	-48.2	1655	-43.2	1550	-43.0	1300	-48.8	1900
30,000 - 40,000	-66.2	1920	-62.7	1665	-68.3	1615	-66.3	2475
40,000 - 50,000	-68.5	2150	-61.8	1550	-76.3	1680	-73.4	2215
50,000 - 60,000	-79.2	1900			-77.3	2400	-76.1	1760
60,000 - 70,000					-75.3	1870	-77.1	1615
70,000 - 80,000					-74.4	1800	-76.1	1830
80,000 - 90,000							-76.1	
Temp. at Burst	-79.2		-66.0		-73.4		-72.5	
Average Rate of Ascent		1629		1421		1529		1743

FACTUAL DATA (continued)

TASK C, Phase 3 (continued)

A study of these figures reveals that the temperatures aloft were indeed unusually low for the Temperate Zone. On seven of the eight flights temperatures below -75°C were recorded; and this, undoubtedly, is part of the reason why the night-flight balloons reached such low altitudes.

However, comparison of the ascensional-rate pattern of these balloons with those recorded in Tables 214, 215 and 217 shows that the flight pattern of the large balloons (3000 grams) with the double tail section is substantially the same as that of the smaller balloon with the single tail section.

Both of these balloons show an acceleration up to speeds in excess of 2000 feet per minute which are generally reached by the smaller balloons at 30,000 feet to 40,000 feet and by the larger balloon at 50,000 feet to 60,000 feet. Only in the case of EX-2C-1208 was an ascensional rate of over 2000 feet per minute reached at 30,000 to 40,000 feet and this was the only balloon to achieve an average ascensional rate in excess of 1700 feet per minute.

The 3000-gram balloon with the shorter tail generally accelerated to an altitude of about 40,000 feet and ascended at a fairly constant rate for the next 40,000 feet. It can be shown that this balloon virtually loses all of its relatively short tail at 40,000 feet and this evidently explains the reason for the constant rate of ascent which occurs. It is, therefore, certain that the 3000-gram balloon which is about 130 inches long, requires a tail section of approximately the same length or slightly greater.

In addition to these large balloons, four balloons in the 2000-gram class were flown. These balloons were made from compound A3-102 a high-modulus compound, and were fitted with a single tail approximately the same length as the balloon. These balloons were all made on a two-necked form, and the tail was attached approximately 15 inches below the equator of the balloon.

The balloons were identified as EX-2C-1211 through EX-2C-1214 and were flown with a total lift of 5950 grams. Their characteristics and flight performance are given in Table 221, and an analysis of the flights is given in Table 222.

A study of these results shows that, although the altitudes are somewhat erratic, the ascension rate is, in general, good and in two instances it is excellent.

FACTUAL DATA (continued)

TASK C, Phase 3 (continued)

TABLE 221

FLIGHT RESULTS - BALLOONS MANUFACTURED FROM COMPOUND A3-102

Experiment No.	Balloon No.	D or N	Balloon Weight (grams)	Balloon Length (inches)	Assembly Weight (grams)	Assembly Length (inches)	Altitude at Burst (feet)	Ascensional Rate (feet/min.)
EX-2C-1211	B 6-1AM	D	1005	77	1895	137	84,000	1927
EX-2C-1212	B13-1AM	D	990	77	1900	127	65,000	1555
EX-2C-1213	B13-2AM	D	975	77	2005	144	77,800	1652
EX-2C-1214	B13-3AM	D	1005	76	1950	143	61,500	2158

The flight of balloon EX-2C-1212 is of particular interest in that the balloon was inadvertently flown inverted. This meant that instead of the tail being attached 15 inches below the equator, it was attached 15 inches above the equator. Its effective length was thereby reduced by approximately 30 inches.

It should be observed that this balloon was much slower over the first 10,000 feet than any of the others. Furthermore, as it expanded, the extremely short tail was very quickly pulled up around the balloon with the result that the assembly now rose at almost constant rate from 10,000 feet to 50,000 feet.

This is exactly in accord with the behavior of the 3000-gram balloon with the shorter tail which also rose at a constant speed over a similar distance. In addition, the rate of ascent of the 1000-gram balloon and the 3000-gram balloon, once the tail has disappeared was almost identical.

TABLE 222

FLIGHT ANALYSIS - BALLOONS EX-2C-1211 THROUGH EX-2C-1214

Altitude Interval (feet)	EX-2C-1211		EX-2C-1212		EX-2C-1213		EX-2C-1214	
	Temp. (°C)	Ascent (ft/min)	Temp. (°C)	Ascent (ft/min)	Temp. (°C)	Ascent (ft/min)	Temp. (°C)	Ascent (ft/min)
0 - 10,000		1545		1160		1485		1360
10,000 - 20,000	-30.5	2250	-30.1	1570	-29.0	1765	-31.6	1840
20,000 - 30,000	-51.2	2385	-49.2	1510	-48.6	2300	-46.2	2975
30,000 - 40,000	-59.2	2010	-57.9	1640	-62.6	2240	-64.8	2490
40,000 - 50,000	-60.6	2020	-59.4	1645	-57.7	1900	-70.2	2550
50,000 - 60,000	-70.4	1930	-70.5	1980	-69.5	1400	-73.2	2115
60,000 - 70,000	-70.6	1790	-70.5	1715	-71.5	1164		
70,000 - 80,000	-70.6	1580			-71.5	1950		
80,000 - 90,000	-68.5	1550						
Temp. at Burst	-68.5		-72.5		-69.5		-73.2	
Average Rate of Ascent		1927		1555		1652		2158

FACTUAL DATA (continued)

TASK C (continued)

Phase 4: Construction of Balloons having Selective Compound Modulation

Some preliminary experiments were conducted with 100-gram balloons in which a modulus differential was created by post-plasticizing a part only of the balloon. It proved possible to induce the balloon to adopt a streamlined shape on inflation by this method.

However, the reduction in modulus induced by post-plasticizing was accompanied by such a sharp loss of tensile strength that the post-plasticized section reached the bursting strength before the rest of the balloon showed virtually any elongation. This, naturally, resulted in an impossibly large reduction in bursting volume.

CONCLUSIONS

TASK A: STUDY OF BALLOON FILMS AND THEIR EFFECT ON BALLOON FLIGHT PERFORMANCE

Phase 1: Study of the Literature

As a result of the study of the literature, samples of Tinuvin 'P', an agent for protection against ultra-violet radiation, and Mobilsol 'L', a new plasticizer, were obtained. In addition, B.T.N., a product of W. T. Henley was found to be identical to N.B.C.

A novel acceleration system for curing neoprene latex at room temperature was also revealed.

Phase 2: Study of Raw Materials

Part A: Neoprene Polymers

The evaluation of six experimental neoprene polymers and four commercial neoprene polymers showed that although ECD-307 has good elongation at -40°C, its room-temperature modulus is very low. However, further work is indicated with this latex with a view to increasing its room-temperature modulus characteristics.

Of the others only ECD-314, which has high ozone resistance, and ECD-418 which cures at very low temperatures are worthy of further investigation.

Neoprene 673 was the only commercial polymer which seemed to be of interest because of its high room-temperature modulus and generally good elongations at room temperature and -40°C. It was subsequently demonstrated, however, that polymers which develop high modulus by virtue of crystallization are unsuitable for use in meteorological balloons.

The use of Neoprene 571 as a means of increasing modulus was shown to be ineffective if Butyl Oleate is the plasticizer. Neoprene 400 is effective even with Butyl Oleate.

A study of the effect of aging neoprene latex before compounding and also of aging the compounded latex showed that no advantages accrue from aging but that there is no loss in physical characteristics after two to three months. There is, however, some variation between different lots of neoprene.

CONCLUSIONS (continued)

TASK A, Phase 2 (continued)

Part B: Plasticizers

A study of the use of blends of plasticizers showed that a mixture of Butyl Oleate and Dibutyl Sebacate was superior to either by itself. Other blends, however, did not show this property.

The examination of Mobilsol 'L' showed it to be of no value as a low-temperature plasticizer in meteorological balloons.

Butoxy Ethyl Oleate from Kessler Chemical was shown to give identical properties to Paraflux C-325 and may be considered a satisfactory plasticizer for use in meteorological balloon compounds.

Ohopex R-9 from Stoney-Mueller and Plasticizer SC from Harwick Standard Chemical Company were both shown to have no value.

Part C: Antioxidants and Antiozonants

Agerite DPPD and Akroflex CD were both shown to be superior antiozonants to N.B.C., with Agerite DPPD much better than Akroflex CD.

Evaluation of Wingstay 'T' revealed that it is of little value as an antioxidant but does increase the elongation of balloon compounds both at room temperature and at -40°C.

It was shown that Lytron 615, a polystrene latex which raises modulus but seriously reduces ozone resistance, can be satisfactorily used in conjunction with Agerite DPPD.

B.T.N. from Henley Chemical Company was proved to be equal to N.B.C. in every way and may be considered as an alternate source of this material.

Part D: Accelerators

The accelerator Merac was shown to give extremely flat-curing compounds and to be very suitable for use in meteorological balloon compounds. Also, the amount of Merac, if 0.5 parts is exceeded, has virtually no effect on the physical characteristics.

Increasing the amount of Accelerator 833, however, increases the elongation at both room temperature and at low temperatures.

CONCLUSIONS (continued)

TASK A, Phase 2 (continued)

It was demonstrated that low-temperature cures can be obtained with Thiocarbanilide. The possibilities of greater uniformity throughout a balloon merit further investigation.

Part E: Polymers other than Neoprene

Poly-isoprene from Shell Chemical Company proved to be unsuitable for use in meteorological balloon compounds in its present latex form.

It was shown that even with the newly developed anti-ozonants the ozone resistance of natural rubber is still much inferior to that of neoprene.

Part F: Reinforcing Fillers

Mistron Vapor was proven to be an excellent reinforcing filler, increasing modulus and tensile strength while permitting the retention of high elongation.

The use of zinc resinate as a means of introducing zinc in an emulsion form proved impractical.

Phase 3: Developments of Formulations with Desirable Film Properties

Part A: High-Altitude Balloon Compounds

Compounds were designed with improved ozone resistance and which still had equal characteristics in other respects. Neoprene 400 was shown to be of value as a means of increasing modulus.

Based on the knowledge gained of the effect of varying compounding materials on the physical properties of neoprene latex, compounds were designed with significantly higher elongations at room temperature and at -40°C. This is almost certainly the most promising method of reaching higher altitudes with balloons of a given size. The achievement of higher elongations of the magnitude attained must be considered of major importance in the design of meteorological balloon compounds.

CONCLUSIONS (continued)

TASK A, Phase 3 (continued)

Part B: Dual-Purpose Balloon Compounds

Several compounds were designed with physical characteristics which indicated that they would produce balloons which will perform satisfactorily by night and by day. It may be concluded that the necessity for post-plasticizing balloons in order to obtain satisfactory night-time performance no longer exists.

Compounds were also designed which have significantly higher elongation at -70°C, than has hitherto been obtainable. The development of such compounds must be considered a major achievement in the development of dual-purpose, high-altitude balloons.

Part C: Fast-Rise Balloon Compounds

A very satisfactory high-modulus compound for use in fast-rise balloons was obtained by the use of Mistron Vapor and the value of this material may be considered as established.

Phase 4: Correlation of Film Properties with Flight Data

Part A: High-Altitude Balloons

Flight tests established that a day-flight balloon weighing about 2500 grams has now been developed, which is capable of reaching altitudes of 130,000 feet at least 60% of the time, and altitudes of 120,000 feet at least 80% of the time. The development of consistently reliable vehicles to such altitudes is of considerable significance.

Flights with larger balloons, however, demonstrated the need for further research to produce reliable 140,000-foot to 150,000-foot vehicles.

Preliminary flights with 1000-gram balloons made from one of the high-elongation compounds developed in Phase 3, Part A, clearly show the possibility of achieving consistent performance at the 120,000-foot level with a balloon weighing little more than 1000 grams.

Part B: Dual-Purpose Balloons

Flights proved that successful dual-purpose compounds have been developed which will provide 1000-gram balloons capable of reaching 100,000 feet by both day and night.

CONCLUSIONS (continued)

TASK A, Phase 4 (continued)

In addition, 2500-gram balloons capable of consistent performance to 120,000 feet were also developed. Consistency at this altitude must be considered a significant achievement.

A 3000-gram balloon established a new world's record for a night-flight balloon, but the consistency of performance at this level still leaves something to be desired.

Flights conducted in the Tropical Zone proved that a balloon capable of flight at night in the Tropics has been developed.

Part C: Fast-Rise Balloons.

No significant developments were recorded in this section.

TASK B: EFFECT OF FLIGHT CONDITIONS ON BALLOON FILM PERFORMANCE

Phase 1: Effect of Pre-elongation

The effect of pre-elongation was shown to explain the somewhat anomalous behavior of day-flight and dual-purpose balloons, and this explanation is a significant contribution to the understanding of balloon flights.

Phase 2: Effect of Ozone

A Bush Ozonator was purchased and shown to be eminently satisfactory for testing of balloon films. A series of tests showed that, whereas day-flight compounds are more rapidly attacked as the elongation increases, dual-purpose compounds are more rapidly attacked at low elongations. This conclusion applies to tests conducted on dumbbell test pieces. The same conclusion is true for inflated patches made from day-flight compounds, but the rate of attack of ozone on patches made from dual-purpose compounds is independent of the elongation.

Phase 3: Effect of Infra-Red Radiation

A comprehensive study of the effect of infra-red radiation was made. It was shown that the theory correctly explains the behavior of balloons in sunlight and at night, and that changes in physical characteristics can be effectively used as a measure of the infra-red absorption.

CONCLUSIONS (continued)

TASK B (continued)

Phase 4: Effect of Ultra-Violet and Other Short-Wave Radiation

It may be concluded that, apart from the creation of ozone, ultra-violet radiation has no adverse effect on meteorological balloon films.

Phase 5: Correlation of Physical Properties with Flight Performance

Flights were conducted with balloons having high infra-red absorption and also with balloons having high infra-red reflectance. The theoretical conclusions were confirmed. It was established that high infra-red absorption reduces the altitude performance in the day-time by as much as 30,000 feet while having little effect at night. High reflectance also appears to slightly reduce day-time altitudes.

Phase 6: Prediction of Balloon Performance

Part A: Determination of Burst Altitude from Residual Elongation

A method of predicting balloon performance from the residual elongation at a given point in the flight was devised and proved to be simple and accurate. A series of nomograms is used.

Part B: Determination of Dimensions of Fast-Rising Balloons

A theoretical study of the dimensions of fast-rise balloons was made. It was demonstrated that, given the performance of a standard thin-walled, spherical sounding balloon, it is possible to predict accurately the performance of fast-rise balloons of varying dimensions made from the same compound.

Part C: Determination of Physical Properties of Constant-Level Balloon Films

The physical properties of balloon films necessary to provide balloons capable of constant-level flight were theoretically determined. It appears that such balloons can be made from existing elastomers.

CONCLUSIONS (continued)

TASK B, Phase 6 (continued)

Part D: Analysis of Stress in Sounding Balloons

A method of determining the point of origin of balloon bursts by photographic means was successfully developed. It was shown to be perfectly feasible to photograph a balloon at the moment of rupture.

Part E: Effect of the Modulus-Elongation Characteristics on the Shape of Inflating Balloons

The significance of the modulus-elongation characteristics of balloon films on the shape of the inflating balloon was proven. It was clearly demonstrated that the slope of the curve rather than intrinsic modulus values is the controlling factor, and this offers another important criterion in the compound selection.

TASK C: STUDY OF BALLOON CONFIGURATION

Phase 1: Design and Construction of Equipment

The difficulties attendant on designing a form and obtaining therefrom a one-piece, streamlined balloon which would maintain its shape during flight were concluded to be too great and this line of attack was abandoned.

Phase 2: Construction of One-Piece Balloons for Flight Testing

A series of flights with tubular balloons led to the conclusion that this type of construction does not produce the desired results in ascensional rate.

Phase 3: Construction of Balloons having Mechanical Attachments to Improve Rate of Ascent

Attaching tails to tubular balloons was shown to be ineffective, and it was clearly demonstrated that the best ascensional rates are obtained using spherical balloons with attached tails. There are strong indications that the shape of the modulus-elongation curve is an important factor in obtaining consistently high rates of ascent, and the dimensions and location of the tail section were also shown to be of vital importance.

Phase 4: Construction of Balloons having Selective Compound Modulation

It was shown that inducing a streamlined shape in a spherical balloon by partial post-plasticizing was accompanied by an unacceptably large loss in bursting volume.

OVERALL CONCLUSIONS

As a result of the study of literature, B.T.N., a product of Henley Chemical, was evaluated as a replacement for N.B.C. and a low-temperature curing system based on Thiocarbanilide was also investigated. In addition, various other compounding ingredients were obtained and examined.

Ten different types of neoprene latex were evaluated, six being experimental; and this investigation, coupled with the evaluation of new plasticizers, accelerators, antioxidants, antiozonants and reinforcing fillers resulted in some significant advances. It was learned that aging of neoprene latex before compounding has no deleterious effect up to three months. Merac was shown to be a very desirable accelerator. Agerite DPPD proved to be a very effective antiozonant but its value is offset due to the darkening of the film which results in lower day-time altitudes because of higher infra-red absorption.

It was shown that by careful selection from the range of compounding ingredients and latices now available, it is possible to increase significantly the elongation obtainable at room temperature and at low temperatures, without reducing room-temperature modulus to a level at which a balloon cannot be handled on the ground.

Flight tests with balloons made from compounds developed during this study resulted in the following achievements:

1. The consistent performance of balloons to 100,000 feet by both day and night has been amply confirmed.

2. Consistent performance to altitudes of at least 120,000 feet has been established. These altitudes can be reached by both day and night.

3. A new altitude record was established at night and the possibilities of reaching altitudes in excess of 140,000 feet at night has been clearly shown.

4. A balloon capable of reaching altitudes of 100,000 feet at night in the Tropical Zone has been developed.

5. New compounds have been developed which indicate the possibilities of reaching much higher altitudes than hitherto attainable. Preliminary flights suggest that 1000-gram balloons capable of reaching altitudes of 120,000 feet are now feasible. Similar gains in altitude at higher levels render flights to above 150,000 feet quite possible.

OVERALL CONCLUSIONS (continued)

In addition to the foregoing, a much clearer understanding of the effects of physical characteristics of the balloon film on the flight performance has been obtained. It is now known that films which show high infra-red ansorption are unsatisfactory for day-flight balloons. Any dark-colored compounding ingredients must, therefore, be avoided. The theory of pre-elongation has been used to explain logically why a dual-purpose compound with an elongation at -40°C substantially greater than that of a day-flight compound does not produce balloons capable of higher altitudes in the day-time. Similarly it explains why dual-purpose balloons of a given size reach the same altitudes by day and by night, although low-temperature physicals suggest that the day-flights should be occasionally higher.

The behavior of both day-flight and dual-purpose compounds upon exposure to ozone has been determined and the differences in behavior established.

A series of theoretical calculations were performed and as a result it is now possible to:

1. Predict balloon flight performance using a group of nomograms based on residual elongation of the film.

2. Predict the performance of all types of balloons, including fast-rise balloons, made from any given compound, knowing the flight performance of one type of balloon made from that compound.

3. Determine the physical properties necessary to have constant-level balloons.

A means of photographing a balloon at the moment of rupture was developed, and it is now possible to determine at what point in a balloon the burst starts.

Also, the significance of the slope of the modulus-elongation curve on the shape and ultimate bursting dimensions of balloons was established and it was shown that measurement of the modulus itself is no criterion.

It was shown that the construction of balloons having an inherent streamlined shape which will be maintained throughout flight is impractical and of questionable value. That a spherical balloon having a conical tail is the most desirable construction for fast-rise balloons was established. The dimensions of such balloons were also determined, and analysis of ascensional rate throughout a flight provided valuable criteria for the design of this type of balloon.

RECOMMENDATIONS

The literature study should be continued. On at least two occasions during the past contracts, valuable information was obtained from this source.

Since DuPont has shown such a cooperative attitude with regard to the development of new polymers designed specifically for meteorological balloons, this phase should be pursued to the maximum. The new polymer samples obtained thus far have substantially added to our knowledge as to what constitutes the most desirable properties in a polymer. Some of the samples already submitted warrant further investigation, and DuPont is now in a much better position to provide latices which produce balloons having higher performance levels.

At the same time, this evaluation should not be restricted to polychlorodrene polymers. Poly-isoprene, butyl, acrylo-nitrile and acrylic latices, both individually and in blends, should be investigated.

Similarly, newly-developed compounding ingredients should be continually sampled and evaluated. In addition, certain materials which proved unsuitable for neoprene may be advantageous when used with other types of latex, and re-evaluation of some of these should be undertaken where indicated.

The failure of Neoprene 673, despite its apparently satisfactory physical properties, suggests that the molecular structure of polymers is of importance. Film structure, as determined by X-ray diffraction studies, should therefore be carried out as a potential means of screening polymers.

Associated with this study, the photographic study of bursting balloons should also be continued. Furthermore, the behavior of small prototypes should also be determined in the cold box when the atmospheric pressure is reduced.

Additional balloons made from the high-elongation compounds already developed should be manufactured and submitted for flight testing.

Raising the bursting altitude of relatively small balloons by increasing the low-temperature elongation of the compound offers one of the most certain methods of producing balloons capable of reaching 150,000 feet.

Balloons weighing 2500 grams have been developed during this contract which consistently reach 130,000 feet, and a 4000-gram balloon from a similar compound should stand a very good chance of reaching at least 150,000 feet.

RECOMMENDATIONS (continued)

The development of similar dual-purpose compounds to the foregoing should also be undertaken.

The studies of pre-elongation, resistance to ozone, infra-red radiation, ultra-violet radiation, and related atmospheric conditions should be extended to any new types of polymer which appear to have interesting properties. It cannot be assumed that the findings which apply to neoprene will necessarily apply to, for example, poly-isoprene.

The design of compounds for fast-rising balloons should be continued, but the development of balloons themselves is presently being undertaken under another research contract. It is not recommended, therefore, that the design of fast-rise balloons be continued as part of this type of research, except insofar as it is necessary to evaluate any compounds developed.

IDENTIFICATION OF KEY TECHNICAL PERSONNEL

Name	Title	Number of Hours
Eric Nelson	Chief Chemist	2344
Nicholas Sisco	Senior Chemist	1239
James Mayes	Senior Chemist	173
Harding Wing	Senior Chemist	1933
Alvin Jampole	Senior Chemist	528
Frederick McWilliams	Junior Chemist	3345
Martin Krentcil	Junior Chemist	2846
Murray Miner	Design Engineer	79

AD ______________ Accession No. ______________ Kaysam Corporation of America, Paterson, N.J. Study of Physical and Chemical Characteristics of Balloons and Balloon Materials By E. Nelson & H. Newstein, Edited by J. Kantor Final Report - December 21, 1962 429 pages, 122 tables, 41 figures Signal Corps Contract No. DA-36-039-SC-84925 and Sig. C. Contract No. DA-36-039-SC-90747 Dept of the Army Project No. 3A99-07-001-08 and Dept of Army Project No. 3M36-21-001-04 Unclassified Report Work was conducted on the following tasks: (A) - STUDY OF BALLOON FILMS AND THEIR EFFECT ON BALLOON FLIGHT PERFORMANCE. The literature was reviewed and several new and experimental neoprene polymers were evaluated. Further evaluation of plasticizers, antioxidants, antiozonants, accelerators was conducted, and polymers other than neoprene plus reinforcing fillers were also examined. Numerous formulations with desirable properties were designed and film characteristics were correlated with flight performance, particularly with dual-purpose compounds. (B) - EFFECT OF FLIGHT CONDITIONS ON BALLOON FILM PERFORMANCE. The effect of pre-elongation, ozone, infra-red and ultra-violet radiation on balloon films was determined, and the results were correlated with flight performance. By utilizing all information acquired in (A) and (B) it was shown possible to predict balloon performance based on laboratory tests much more accurately than heretofore. (C) - STUDY OF BALLOON CONFIGURATION. Balloons having shapes other than spherical were manufactured both in prototype and production sizes, and the flight performance of such balloons was determined. Both the altitudes achieved and ascensional rates were studied.	Unclassified Meteorological Balloon Film Development Signal Corps Contract Nos. DA-36-039-SC-84925 and DA-36-039-SC-90747

METEOROLOGICAL DIVISION
SURVEILLANCE DEPARTMENT
U. S. ARMY ELECTRONICS RESEARCH AND DEVELOPMENT LABORATORY

DISTRIBUTION

Organization	No. of Copies
Commanding General U. S. Army Electronics Command ATTN: AMSEL-AD Fort Monmouth, New Jersey	1
Commanding General U. S. Army Electronics Command ATTN: AMSEL-MS Fort Monmouth, New Jersey	1
Commanding General U. S. Army Electronics Command ATTN: AMSEL-RE-C Fort Monmouth, New Jersey	1
Chief Signal Officer Department of the Army Washington 25, D. C.	1
Commander Wright Air Development Division ATTN: WWAD Library Wright-Patterson Air Force Base, Ohio	1
Commander Rome Air Development Center ATTN: RAOIL-2 Griffiss Air Force Base, New York	1
Hqs, Air Weather Service (MATS) U. S. Air Force ATTN: AWSSS/SIPD Scott Air Force Base, Illinois	1
Commander Air Force Cambridge Research Laboratories ATTN: CRZW L. G. Hanscom Field Bedford, Massachusetts	1
Commander Air Force Command and Control Development Division ATTN: CRO L. G. Hanscom Field Bedford, Massachusetts	1

DISTRIBUTION (continued)

Organization	No. of Copies
Commander Armed Services Technical Information Agency Arlington Hall Station ATTN: TISIA Arlington 12, Virginia	10
Director U. S. Naval Research Laboratory ATTN: Code 2027 Washington 25, D. C.	1
Office of the Assistant Secretary of Defense (Research and Engineering) ATTN: Technical Library Room 3E1065, The Pentagon Washington 25, D. C.	1
Aeronutronic Division of Ford Motor Company Ford Road Newport Beach, California	1
Commanding Officer and Director U. S. Navy Electronics Laboratory ATTN: Library San Diego 52, California	1
Chief Bureau of Naval Weapons (FAME) U. S. Navy Department ATTN: Head, Aerology Branch (MA-5) Washington 25, D. C.	1
Director, Bureau of Research and Development Federal Aviation Agency Washington 25, D. C.	1
Commander Hq. Air Research and Development Command (RDRS) Andrews Air Force Base Washington 25, D. C.	1
Office of Chief of Research and Development Department of the Army ATTN: CRD/M Washington 25, D. C.	1

DISTRIBUTION (continued)

Organization	No. of Copies
Chief United States Army Security Agency ATTN: ACofs, G4 (Technical Library) Arlington Hall Station Arlington 12, Virginia	1
Commanding Officer U. S. Army Electronics R&D Activity ATTN: Meteorological Department Fort Huachuca, Arizona	1
Library, Boulder Laboratories National Bureau of Standards Boulder, Colorado	1
Commanding Officer U. S. Army Electronics Material Support Agency ATTN: SELMA-ADJ Fort Monmouth, New Jersey	1
Commanding Officer U. S. Army Electronics Research and Development Laboratory ATTN: Director of Research Fort Monmouth, New Jersey	1
Commanding Officer U. S. Army Electronics Research and Development Laboratory ATTN: Chief, Technical Information Division Fort Monmouth, New Jersey	1
Commanding Officer U. S. Army Electronics Research and Development Laboratory ATTN: Adjutant Branch, Mail File and Records Fort Monmouth, New Jersey	1
Transportation Officer for Activity Supply Officer USAELRDL, Logistics Division Building #2504, Charles Wood Area Fort Monmouth, New Jersey ATTN: SELRA/SMS Contract No. DA36-039 SC-90747	6